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The University of Southern Mississippi

A COMPARISON OF HABITAT AND GEOMORPHIC CHANGES ON EAST SHIP VERSUS SAND ISLANDS MISSISSIPPI, 2007-2014

by

Carlton Peter Anderson

A Thesis
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Approved:

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ABSTRACT

A COMPARISON OF HABITAT AND GEOMORPHIC CHANGES ON EAST SHIP VERSUS SAND ISLANDS MISSISSIPPI, 2007-2014

by Carlton Peter Anderson

May 2015

The islands of the Mississippi-Alabama (MS-AL) barrier island chain along the micro-tidal northern Gulf of Mexico are highly dynamic coastal features subject to rapid changes in habitat, geomorphology, and elevation by natural and anthropogenic disturbances, such as hurricanes, subsidence, sea-level rise, and dredging activities. The purpose of this study was to compare elevation, total volume, habitat-type coverage, and short-term change between "naturally" formed East Ship Island and "man-made" Sand Island (Disposal-Area 10). This study used a combination of repeat photography, ground elevation measurements, and multi-year remotely sensed data to produce photographic pairs, habitat classifications, and digital elevation maps to quantify short-term change. Changes to both islands followed two moderately-sized hurricanes in 2008 and 2012. Sand Island experienced land loss, and East Ship Island had land area gain following the 2012 hurricane. Reductions to the beach dune herbland habitat coverage on both islands were a direct result of these events. However, rapid recovery (~1.5 to 2 yr) of the habitat was observed in 2010 and again in 2014, suggesting these storms were actually beneficial to the islands. Fluctuations in coverage for all common habitats were similar on both islands, with the exception of marsh shrubland. Similar ranges of elevations (MSL) were found for habitats on both islands, with transitions of habitats occurring approximately

every 0.3 m of increase or decrease. Although different in age, these two islands show remarkable similarities in habitat make-up and geomorphic features.

DEDICATION

To my mother, Debbie Anderson, I cannot express enough how grateful I am. You have supported me in every way and instilled values in me that I will carry with me forever. To my family members and friends who are gone but not forgotten: Daniel Partin, a friend who always encouraged me to not settle, and to aim to achieve my goals; Amber Anderson Meyer, my sister, who has inspired me to live my life to the fullest and to have an open mind; Larry Darwin Anderson, my father, who taught me dedication and a strong work ethic goes a long way in life; Peter Martin Johanson Sr., my grandfather, who helped to shape and grow my passion for science and the outdoors by loving and caring for nature. Further, this thesis is dedicated to all my family, friends, and my special who have helped me with their love, while providing guidance, motivation, and support during the time of this research.

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TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF ILLUSTRATIONS

Figure

LIST OF ABBREVIATIONS

BV .... Brightness Value

DA-10 .... Disposal Area 10

DTM .... Digital Terrain Model

GCGC .... Gulf Coast Geospatial Center

GCP .... Ground Control Point

GIS .... Geographic Information Systems

GPS .... Global Positioning Systems

GSD .... Ground Sample Distance

GUIS .... Gulf Islands National Seashore

LAS .... Laser File Exchange Format

LIDAR .... Light Detection and Ranging

MS-AL .... Mississippi-Alabama

ML .... Maximum Likelihood

NAD83 .... North American Datum 1983

NAIP .... National Agriculture Imagery Program

NASA .... National Aeronautics and Space Administration

NGOM .... Northern Gulf of Mexico

NOAA .... National Oceanic and Atmospheric Administration

NPS .... National Park Service

ROI .... Region of Interest

RTK .... Real Time Kinematic

USACE .... United States Army Corps of Engineers

CHAPTER I

INTRODUCTION

Problem Statement

In recent years there has been a major emphasis on the restoration of the barrier islands off the Mississippi and Alabama (MS-AL) coastlines, following Hurricane Katrina (2005). Many plans have been adopted in an effort to aid and support their natural growth and maintenance (USACE, 2014). The MS-AL barrier islands have been extensively studied in respect to their habitat and geomorphic changes since the early and mid-20th century (Otvos, 2012). In review of the literature concerning the MS-AL barrier island chain, it was noted there was a lack of research solely focusing on the short-term evolution of these barriers in terms of their habitat development and geomorphology. Many studies have focused on long-term development of these barriers through decadal classification of habitats and geomorphic dynamics, such as island formation and alteration. Barrier islands border approximately 10% of the world's open ocean shorelines, with 35% of those barrier islands in North America (Cooper, 2007; Pilkey, Cooper, and Lewis, 2009; Lucas and Carter, 2010; Stauble, 1989). The United States has seen rises in population along its coastlines, which have led to the private and commercial development of its coastal shorelines (Ruppel, Schultz, and Kruse, 2000). Barrier islands provide a vital role to the resiliency of natural and man-made coastal ecosystems by buffering coastlines from tropical events and every-day wind and wave energies.

These systems are susceptible to saltwater toxicity with the effects of sea-level rise due to their low land-sea interface, making them indicators of global climate change

(Aguilar *et al*., 2012). Barrier islands composed mostly of quartz sand geology are also susceptible to fluvial and aeolian erosion. Historically, their sediments have been recharged through the natural process of longshore drift; however, their current replenishment is being hindered through the channeling of shipping lanes in the Mississippi Sound, acting as traps (Otvos and Carter, 2008). Although plans have been made to mitigate sediment depletion, they have not been fully implemented. It has been generally accepted that the presence of a freshwater lens indicates the overall sustainability of a barrier island, and is considered to be a feature that drives habitat development (Schneider and Kruse, 2003).

The MS-AL barrier island chain is composed of landforms that are constantly transformed by changes through meteorological events, sediment supply, and sea-level rise as they progress through their evolutionary process (Otvos and Carter, 2008). The chain consists of both natural and man-made barriers that have evolved from natural processes and the artificial deposition of dredge spoil. The natural barriers in the chain are thought to have formed roughly *ca.* 4.5 ka from the slowing of sea-level rise during the Holocene Transgression (Otvos and Carter, 2008). As mentioned previously, relatively little attention has been given to the short-term development of both natural and man-made barriers in the chain. While research has been conducted on vegetated habitats and geomorphic dynamics, it has solely focused on the natural islands in the chain. East Ship Island and Sand Island offer a chance to compare a naturally formed island to one that has naturally aggregated from dredge spoil, creating in essence a man-made island.

Tentative plans call for the removal of a portion of the man-made Sand Island to be used for the restoration of the natural East Ship Island (USACE, 2014). The specific problem is short-term vegetation succession on the MS-AL barrier island chain, both for natural and man-made islands, is currently not well understood. Thus, the objective of this study was to investigate short-term habitat and geomorphic change between a natural and man-made barrier island, in respect to elevation, total volume, habitat type and coverage, using remotely sensed data and field observations through repeat photography. Short-term is defined in this study as the time period from 2007 to 2014. The overarching goals of this research were to 1) determine types of habitat and their total coverage found on both islands, examine them individually, and compare them to each other, 2) determine elevation and total volume of each island, examine them individually, and compare them to each other and 3) determine the short-term evolution of both a man-made and a natural barrier island. The main research questions in this study are: 1) what characteristics of the vegetated habitats and geomorphic features on these two islands have changed from summer 2007 to summer 2014? 2) How different are the vegetated habitats and geomorphic features between a natural island and one that has been created through man-made activity? 3) Is there a prescribed amount of time for the genesis of a dredge spoil to be considered a barrier island?

Significance of Study

Biogeography as discipline has roots that extend back to Aristotle (384 – 322 B.C.) when, as a student, he developed methods for classifying plants and animals into an early basic taxonomic system (McDonald, 2003). Aristotle's teacher and mentor, Plato, also had an inquisitive mind, and gave qualitative insight into the eroding hills of Greece due to the lack of flora supporting the degrading soils, paving the way for study in Geomorphology (Martin, 2005). The basic scholarship and inquiry of the geographic distributions of past and present animal and plant species, and how the Earth's landforms have evolved have not changed to this day. Researchers are constantly seeking to determine what effects both the natural and human environment have on present and future plant and animal species colonization in a given area.

Many studies have focused on the biogeography of vegetated habitats and the geomorphology on East Ship Island. It has been noted that changes in elevation are a direct determinant of species type and ultimately habitat diversity (Doyle *et al.*, 2010; Lucas and Carter, 2010). Habitats such as marsh exist at lower elevation while shrublands and pine forest are found at higher elevation (Lucas and Carter, 2008). Further, the literature on the geomorphic dynamics along the chain have been exclusively long-term studies concerning sediment supply, land loss and gain, and formation, suggesting a depletion in the overall sediment budget and island migration (Byrnes *et al.,* 2012; Morton, 2008; Otvos, 1981; Otvos, 1985; Otvos and Carter, 2013). Currently there is no literature solely focused on Sand Island. This leaves a gap in the literature that needs to be explored and understood.

By utilizing a comparative study using remotely sensed data and repeat photography between the natural East Ship Island and the man-made Sand Island, new insight will be gained on the biogeographic and geomorphic tendencies of these two islands through a short temporal scale study. The need to understand these dynamic features off the MS-AL coast is vital to the general populations that reside in coastal areas. Further, using a comparative study will give a better understanding into the elevation and the habitat that is supported at those elevations. Impacts from island restoration can also be better understood, allowing for cheaper, quicker, and more efficient repeat studies. This study will make several contributions to the field of Geography and several of its sub-disciplines. It is the first study that compares a natural and a man-made barrier island in the Northern Gulf of Mexico (NGOM), and will provide insight to succession in short-term scales. As noted by other researchers, elevation can be a key factor in the type of vegetation species found on barrier islands. This research makes contributions to Ecology, Geology, and Geomorphology by using fine scale resolution Light Detection and Ranging (LIDAR) to determine how elevation can affect the type and coverage of differing habitats. By understanding the short-term evolution on these two small barrier islands, biogeographers can implement sea-level rise models to better understand habitat succession from the effects of global climate change. Local planners, engineers, and policy makers will better understand successional patterns on these barrier islands, allowing them to introduce new policies that will help mitigate the cost of island restoration, while maintaining their stability.

Background of Chapters

In order to address the specific research questions of this thesis, it has been divided into two major research components: 1) using remote sensing to compare habitat and elevation, as well as changes in habitat on East Ship and Sand Island and 2) using repeat photography to interpret habitat change. This thesis consists of five chapters. Chapter I introduces the study and its overall importance to the discipline of Geography. Chapter II provides a background of the MS-AL barrier island chain, its geologic framework, and vegetation found throughout the chain. The chapter also introduces the two study sites, East Ship and Sand Islands. Chapter III focuses on the use of remotely sensed imagery acquired in 2007, 2009, 2010, and 2012 to show habitat classifications and changes between those years on both East Ship and Sand Island. Further, the chapter deals with the use of LIDAR acquired in 2012 to make Digital Terrain Models (DTM) and elevation analysis on both islands. Chapter IV investigates the use of repeat photography as a method of determining change in habitat on both East Ship and Sand Island between 2010 and 2014. Chapter V revisits previous chapters, and provides conclusions, using the results from the remote sensing and repeat photography analysis to provide insight to the research questions.

CHAPTER II

THE MISSISSIPPI-ALABAMA BARRIER ISLAND CHAIN

Geologic and Vegetation Framework

Barrier Island Formation Theories

Many theories have been postulated on the formation of the MS-AL barrier island chain. Barrier islands are found throughout the world in various types of tidal environments, but favor marginal marine settings with aggradational coastlines that have an active means for sediment deposition (Otvos, 2012; Pilkey, 2003). The shallow sloping continental shelf off the MS-AL coast in the NGOM provides an environment fit for aggradation. The region has five quartz sand dominated naturally occurring barrier islands, with one formed from dredge spoil, that have been shaped throughout the Holocene. The natural islands of the chain in geographical order from west to east: Cat, West and East Ship, Horn, Petit Bois, and Dauphin (Figure 1).

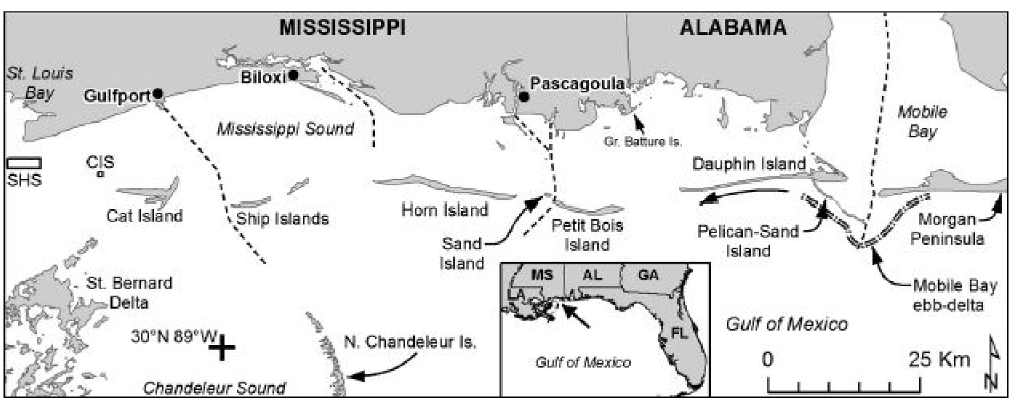


Figure 1. Map showing the natural and man-made islands of the MS-AL chain. Dashed lines represent navigation channels. Map was used with permission from Otvos and Carter, 2013. Regressive and transgressive barrier islands on the North-Central Gulf Coast – Contrasts in evolution, sediment delivery, and island vulnerability. *Geomorphology*, 198(1), p. 2.

It has been suggested there are three major criteria that need to be met in order for the formation of barrier islands. The first is an active supply of sediment in the form of quartz grains transported by riverine and deltaic processes, the second is tidal cycles with low ranges, and the third has been previously mentioned, a low sloping continental shelf (Pilkey, 2003). Further, longshore drift as an active means for transport of sediments needs to exist. The Holocene Transgression, a period marked by rapid sea-level rise, where eustatic sea-levels rose by as much as 110-113 meters, initially began about *ca.* 18.0 ka and lasted till about *ca.* 6.0 ka (Davidson-Arnott, 2010). Through foraminifera and other geologic studies, the chain is thought to have formed under micro-tidal influences with the slowing sea-level rise at the end of the transgression about *ca.* 4.5 ka (Morton, 2008; Otvos, 1981; Otvos and Carter, 2008; Otvos and Giardano, 2004).

Barrier platforms are sub-aerial shoals considered to be the foundation on which the MS-AL barrier island chain lies. They provide structure and stability, and are an essential part of the island-lagoonal complex (Otvos, 2005; Otvos, 1985). It has been documented there are three main types of platforms, which are generally linear or arched in shape. However, ebb-tidal platforms, such as the one that anchors the Chandeleur Islands off the coast of Louisiana, do show characteristics of being semi-circular in shape. Considered to be the dominant platform type on the chain, the aggradational-progradational platform consists of Pleistocene sediments over-lain by Holocene muddy deposits that have been reworked by shoaling to form sandy deposits that develop into a platform (Otvos, 1985). Four of the five naturally occurring islands in the MS-AL chain have formed on aggradational-progradational platforms. Dauphin Island is considered to have formed on a composite platform, developed through ridge engulfment of Pleistocene highlands (Otvos, 1985). The third is the transgressive platform, where sediments are deposited on bays, estuaries, lagoons, and deltaic sediments.

Spit detachment, mainland beach detachment, and near shoal aggradation are several leading theories that have been used to explain the formation of barrier islands (Davis Jr. and Barnard, 2003; Flocks *et al.,* 2009; Otvos, 1985; Shwartz, 1971). Spit detachment barrier islands are formed by elongated narrowing spits that are susceptible to overwash and erosion creating new tidal inlets. These new tidal inlets sustain themselves through tidal fluctuations, creating separation between detached spits and forming new barrier islands (Otvos, 1985). Petit Bois Island is thought to have formed this way from a breach initially caused by a hurricane in the 1700s and the subsequent separation from Dauphin Island (Otvos and Carter, 2008). Mainland beach detachment is characterized by the engulfment of Pleistocene high lands, or beach ridge complexes (Shwartz, 1971). Generally, a high beach ridge is backed by a gently sloping coastal plain, providing a zone for flooding. The flooded coastal plain produces a lagoon, and preserves the dune complex through the reworking of sediment. Dauphin Island is thought to have formed around a mainland detached beach dune complex. Sediment cores sampled in the area indicate an area of exposed Pleistocene sediment at the surface (Otvos, 1985). Another leading theory is that of near shoal aggradation. This takes place when intertidal influences cause swash bars to form, trapping flotsam and other sediments, which lead to the growth of fauna on exposed bars during low tidal situations (Otvos, 1981). Some barrier islands off the west coast of Florida are thought to have formed in this manner (Davis *et al.*, 2003; Otvos, 1981).

Origins of Sediment

The MS-AL barrier chain can attribute the majority of its sediments to two main sources. Early in the formation of the chain and throughout much of its development, the major source of sediment was from the erosion and recycling of Appalachian Mountain sediments. Sediment sources from the Appalachian Mountains and its foothills include: the Piedmont from Georgia, Alabama's Valley and Ridge Province, and The Blue Ridge Mountains of Tennessee (Byrnes *et al.*, 2013). Another sediment source comes from the headlands of the Florida-Alabama coast (Cipriani and Stone, 2001). Sands being transported from the Florida-Alabama coast have contributed to the formation of the Mobile Pass ebb shoal (Byrnes *et al.,* 2012; Otvos and Giardino, 2004). Evidence shows that the quartz rich shelf east of the Mobile Pass ebb shoal is the primary source of sediment for tidal shoals in the Mississippi Sound (Byrnes *et al.*, 2012). Typical sediment types found in the Mississippi Sound are also consistent with those found off the Florida-Alabama coast, with only 2% carbonates and heavy minerals, such as tourmaline, hematite, kyanite, and staurolite (Cipriani and Stone, 2001). However, Otvos and Carter (2008) still suggest the Mobile-Tensaw River System accounts for a significant portion of sediments found in the tidal shoals, platforms, and barrier islands on the chain.

Sediment Transport

The active transportation of sediment in the chain is provided by two primary mechanisms. The Mobile-Tensaw River System is the second largest river delta in the United States, covering about 775 km^2, and consisting of bottom hardwood forest, marsh, swamp, and open water habitats (Byrnes *et al.*, 2012). Only two rivers directly discharge into Mobile Bay; however, five additional major rivers are confluenced into the basin. Eroded Appalachian quartz sands are recycled and transported down the system where they are eventually carried through the Mobile Pass and worked into littoral zones through the progradation of the Morgan Peninsula barrier (Otvos and Carter, 2008).

Sediments originating both from the Florida-Alabama coast and the Appalachian Mountains are transported by longshore currents, waves, tides, and littoral drift. Due to dominant southeast prevailing winds, the primary current and drift direction are from east to west. Research on sediment transport by Cipriani and Stone (2001) shows the presence of six littoral cells extending from Dauphin Island to West Ship Island that drive transportation of sediment. Cell one, located off the eastern end of Dauphin Island's exposed Pleistocene highland, extends 6 km to the west, showing traits of eastward drift with increasing magnitude down the length of the cell (Cipriani and Stone, 2001). Cell two is located on the western end of Dauphin Island. Cell two increases with magnitude down drift of its starting point, and has a westward drift as opposed to eastward drift. Westward drift cell three starts at Petit Bois Island's east end and works its way to the islands central portion. Drift slows down, and is believed to stop at the end of cell three. Cell four is a westward drift cell considered to be the most stable out of the six extending from the central portion of Petit Bois Island to Horn Island Pass. As with cell four, cell five is also a westward drift cell, and is considered to be fairly stable as it extends down the entire length of Horn Island. The final westward drift cell is located off East and West Ship Island, with no breaks between the tidal inlet (Cipriani and Stone, 2001). Attempts to quantify the amount of sediment transported through these cells have seen mixed reviews, as they are primarily based on modeling from waves, tides, and bathymetric data. The postulated presence of these cells indicates drift direction and helps to quantify land loss and gain on the chain (Byrnes *et al.*, 2012; Cipriani and Stone, 2001).

Erosion

Everyday natural events, such as wave action, tidal fluctuations, and aeolian processes, cause erosion on the chain; however, tropical cyclonic activity and winter cold fronts exacerbate these conditions. Many studies have been conducted on land loss after tropical events, and there is a direct link between wind speeds, landfall proximity, and height of storm surge to overall land loss (Morton, 2008). Storm surge arguably has the biggest implications on a barrier islands geomorphic change through two types of overwash situations. Run-up overwash is characterized by surge flooding of the island in all areas, except for the backshore dunes. Sediments are entrained and pulled back into the ocean side of the barrier, causing destabilization of the foredune system (Morton, 2008). Most tropical events that impact the chain have run-up overwash as they generally produce storm surge heights under 3-4 m. However, run-up overwash can create scouring and blowouts, reshaping dunes (Maun, 2009; Morton, 2008). Inundation overwash is the complete submergence of a barrier island, characterized by over-topping of both fore and back dunes. Inundation overwash creates scouring and blowouts, but also spills into the back lagoon, creating major erosion on lagoonal-facing beaches and dunes during surge retreat (Morton, 2008; Otvos and Carter, 2008). This type of overwash can be catastrophic, and takes many years for a barrier to be replenished of eroded sediments during these conditions. Several instances of inundation overwash have occurred in modern history on the MS-AL barrier island chain. Hurricanes Camille (1969), Fredric (1979) and Katrina produced inundation overwash (Otvos and Carter, 2008). There has been little research concerning the causation of winter cold fronts leading to erosion on the chain. Winter storms are a viable source of erosion as they occur more frequent than tropical events (Keen, 2002). After the passage of a winter cold front, fetch from the north and northwest actively erodes and entrains sediment on the lagoonal-face of the barriers, causing a narrowing of the island. As narrowing occurs, the island becomes more vulnerable to overwash and new tidal inlets can form. Eroded sediments deposited in tidal inlets are usually inhibited from reaching littoral cells on the ocean side of the barrier (Keen, 2002).

Deposition

Westward littoral drift processes drive the natural deposition of sediment on the MS-AL barrier island chain. Sands, silts, and clays enter littoral cells that overlay barrier platforms, where longshore currents deposit these sediments on the platform or shore-face of a barrier island (Cipriani and Stone, 2001). Silts and clays are usually reworked due to their smaller size, leaving heavier quartz grain sands behind on the shore-face. Entrainment is higher during wave strike in the swash zone of the shore-face, providing a means for transportation and deposition of sands. Entrainment drops as waves recede, causing reworking of sands in the swash zone, leading to island migration. Sands can also be further reworked into fore and back dune systems through fluvial and aeolian processes. Depending on wave strike angle and the bathymetry of the platform, portions of the island can be totally reworked, creating new features. Cat Island shows characteristics of shore-face and spit reworking due to the transgression of the Old St. Bernard Delta Lobe (Rucker and Snowden, 1990; Rucker and Snowden, 1989). During the transgression, ~3.0 ka, a north-south spit emerged on the eastern end of the island. This was a result of southeast fetch previously hindered by the presence of the delta (Rucker and Snowden, 1990; Rucker and Snowden, 1989).

Sediment Budget

The use of computer simulated models using wavelength, wave heights, tides, and updated bathymetric maps have allowed for a more accurate depiction of the sediment budget for the MS-AL barrier island chain (Byrnes *et al.*, 2013; Byrnes *et al.*, 2012). Starting with Dauphin Island, the computed sediment budget is ~4,000 m^3/yr. The significance of this figure is that it is located in littoral cell one, south of the island, and is dominated by eastern drift, creating a spit feature called Pelican Sand Island (Byrnes *et al.*, 2013; Byrnes *et al.*, 2012; Cipriani and Stone, 2001). From the western portion of Dauphin Island down to central Petit Bois, about 227,837 m^3/yr of sediment is accounted for in the budget, providing a net source of sediment to down-drift beaches. Further, from the central portion of Petit Bois Island to the eastern end of Horn Island, ~334,110 m^3/yr of sediment is available in the budget. Due to the presence of a major shipping lane, ~16,820 m^3/yr of sediment is lost in the Horn island Pass, allowing the remaining 312,702 m^3/yr to nourish the remaining length of Horn Island (Byrnes *et al.*, 2013; Byrnes *et al.*, 2012). However, Horn Island actually contributes to the budget by as much as 10,000 m^3/yr. After crossing the Dog Key Pass on its way to the Ship Islands, the budget is reduced considerably with only ~109,331 m^3/yr of sediment available for the replenishment of these islands (Byrnes *et al.*, 2013; Byrnes *et al.*, 2012).

Anthropogenic Activities

In modern times anthropogenic activities have played a major role on the transportation, erosion, and deposition of sediments on the MS-AL barrier island chain. These impacts have had direct effects on the biota and geomorphic make-up of these islands (Morton, 2008; Otvos and Carter, 2008). During the middle part of the 1800s the advent of larger ships needing to enter the ports of Mobile, Pascagoula, and Gulfport led to the channeling of several natural tidal inlet passes to support local economies. The Port of Mobile initially dredged its channel to a depth of 3 m, running from the east end of Dauphin Island through Mobile Bay (Morton, 2008; Morton, 2010). Since its original dredging, this channel has been subsequently widened and deepened five additional times throughout its history. The present channel has a depth that is about 10 m deeper and 100 m wider than the original channel (Morton, 2008). After the initial dredging of the Mobile Ship Channel, Pascagoula and Gulfport soon followed suit with their own dredging projects. The Pascagoula Ship Channel runs north-south through the Horn Island Pass on the west end of Petit Bois Island. The Gulfport Ship Channel lies off the west end of Ship Island. These two channels have also been widened and deepened since their initial dredging. There are only two inlets that have not been impacted by dredging operations. The only totally preserved natural tidal inlet in the MS-AL barrier island chain is the Dog Keys Pass between Horn and East Ship Island (Morton, 2008). The influences these channels have on the chain are drastic. Entrainment values are lost as sediments enter littoral cells on their journey from east to west down the chain. Once entrainment values are lost, deposition occurs in the ship channels, requiring further excavation of material to maintain required depths for large draft vessels. In the past, excavated material was artificially deposited on dredge spoil sites too far offshore for entrainment in longshore currents. This has led to a decline in sediment available to the MS-AL barrier islands, thus starving the chain (Morton, 2008; Otvos and Carter, 2008).

Traditionally, the dredge spoil of these shipping channels has been deposited in locations known as spoil areas. Many of these sites are located several miles south of the chain in deep water (Morton, 2010; Morton, 2008; Otvos and Carter, 2008; USACE, 2014). However, one site known as Disposal Area 10 (DA-10), located in the Horn Island Pass west of the Pascagoula Ship Channel, has been actively prograding since initial deposition at the site (Otvos and Carter, 2008; USACE, 2014). Through sediment progradation, its location in the chain, and subsequent artificial deposition at the site, the spoil area has emerged as an aerial feature. The U.S. Army Corps of Engineers (USACE) has proposed plans to use sections of this dredge spoil island to restore portions of eroded islands throughout the MS-AL chain (USACE, 2014). The plan calls for the removal of a portion of DA-10 as a sediment borrow sight for the filling of Camille Cut, located between East and West Ship Island (USACE, 2014). According to the USACE, two options exist for the borrowing of sediment at DA-10. The first would impact a natural freshwater pond, while option two would avoid the wetland; however, both options ultimately affect natural habitats (USACE, 2014).

Geomorphic Response

The barrier islands all have different geomorphic responses to the natural and anthropogenic effects of erosion, transportation, deposition, and budget of sediment. Research has identified eight major geomorphic responses to the aforementioned processes, to include: lateral movement, advance, dynamic equilibrium, retreat, in-place narrowing, landward rollover, and rotational instability (McBride, Byrnes, and Hiland, 1994). Only a few of these types affect the MS-AL chain; yet, a brief introduction into the responses is needed for an understanding of the processes at work on the chain.

Lateral movement is characteristic of sediment transport shore-parallel involving lateral accretion downdrift of an erosional site. Advance is a geomorphic response typical of a prograding coast in a shore-normal direction, found where sediment supply is abundant. Dynamic equilibrium is dominated by a stable shoreline, whose supply of sediment is constant and does not fluctuate positively or negatively. In-place narrowing occurs when the lagoonal side and gulf or ocean sides of the islands erode faster than deposition can occur. This type of response typically takes place during winter months, as dominant fetch is shifted (McBride, Byrnes, and Hiland, 1994). In-place narrowing can lead to island breakup, as is seen in many Louisiana deltaic barrier islands. Landward rollover is dominated by multiple instances of overwash, as sediment is deposited on the lagoonal side of the island. Rotational instability is the least understood type of geomorphic response. It can be explained by the rotation of the island about a stable midpoint, typically having one end of the island migrating landward and the other seaward (McBride, Byrnes, and Hiland, 1994). Of the islands in the MS-AL barrier island chain, Dauphin, Petit Bois, and Horn Island are currently undergoing lateral movement, while Ship Island is experiencing rotational instability, and Cat Island is in retreat (McBride, Byrnes, and Hiland, 1994).

Vegetation

The MS-AL barrier island chain is composed of various habitats that are constantly being altered by the elevation of the water table, land, and sea (Lucas and Carter, 2008). These habitats are for the most part adaptable to many harsh environments, such as high concentrations of salt spray, drought, fresh and saltwater flooding, partial burial in sand, and lack of soil nourishment (Lucas and Carter, 2008; Oosting, 1954; Shao, Shugart and Hayden *et al.*, 1996). Many species of vegetation can be found at various elevations across the chain in differing types of habitats. Several studies have been conducted on the plant species richness, decadal changes of species, and relationships between dune plants and geomorphic systems (Lucas and Carter, 2010; Lucas and Carter, 2008, Penfound and O'Neill, 1934; Stallins, 2002).

There are many species of flora that dot the landscape of the MS-AL barrier island chain. While this list does not comprise the entirety of species on the chain, it does highlight the dominant species that make up particular habitats. Starting in lower habitats that are dominated mainly by periodic saltwater intertidal flooding, plant species such as saltmeadow cordgrass (*Spartina patens*), smooth cordgrass (*Spartina alterniflora*), and black needle rush (*Juncus roemerianus*) can be found. In freshwater pond areas the common reed (*Phragmites australis*) is typically found (Adams, 2008; Cho, 2011; Lucas and Carter, 2008). At slightly higher elevations, habitats are described as meadows by Lucas and Carter (2008), consisting mainly of torpedo grass (*Panicum repens)* and goldentop (*Euthamia leptocephala*). Dune habitats are dominated mainly by grasses tolerant to salt spray and frequent sand burial, with species such as beach morning glory (*Ipomoea imperati*), sea oat (*Uniola paniculata*), and gulf bluestream (*Schizachyrium maritimum*) (Adams, 2008; Cho, 2011; Maun, 2009; Stallins, 2002). Yaupon holly (*Ilex vomitoria*), marsh elder (*Baccharis halimifolia*), and wax myrtle (*Myrica cerifera*) can be found in transition zones from marshes, meadows, and dunes to woodland habitats (Adams, 2008; Lucas and Carter, 2008). Woodland habitats are dominated with species such as sand live oak (*Quercus geminata*) and slash pine (*Pinus elliottii*) (Lucas and Carter, 2008).

The presence of a freshwater lens on a barrier island indicates stability, and ultimately can determine the type of vegetation found (Schneider and Kruse, 2003).

Little is currently known about freshwater lens phenomena on a barrier island, although it has been suggested that elevation and vegetation play a vital role in lens height. Schneider and Kruse (2003) conclude that dune vegetation allows for the fast recharge of a barrier island freshwater lens, while low-land marsh and shrub-land areas promote evapotranspiration.

The vegetation on coastal barrier islands is constantly undergoing change through tropical cyclonic impacts and relative sea-level rise. Hurricanes and tropical storms overwash low-land areas, depositing sands and other sediments on vegetation, requiring the survival or reestablishment of affected species. Further, saltwater toxicity and high wind speeds can have drastic effects on woodland species, such as slash pine and sand live oak. According to Hughes (2008), in the wake of Hurricane Katrina, Horn Island experienced an 80% slash pine mortality, while East Ship Island saw total destruction of slash pine, a 100% loss.

As relative sea-level rise continues, the successional pathways these habitats undergo will adjust in response to micro changes in elevation (Lucas and Carter, 2010; Doyle *et al.*, 2010). Recent reviews of works conducted on rates of sea-level rise in the NGOM show a range of about 2.0 and 3.0 mm/yr., and are on the fringe of reaching early Holocene levels (Anderson *et al.*, 2013; Doyle *et. al*, 2010). Further, coastal subsidence, another factor that comes into play along the NGOM, exacerbates rates of relative sea-level rise in the area by as much as 10 mm/yr. (Anderson *et al.*, 2013). Coastal subsidence along the NGOM is lower in the eastern and western gulf, with higher rates in the central NGOM. Although these rates sound alarming, they are hard to constrain due to differences in subsidence across the region (Anderson *et al.*, 2013; Doyle *et al.*, 2010).

Study Area

East Ship Island

East Ship Island, located at (30.237, -88.887), is composed mostly of quartz sand with finer silts and clays on its lagoonal side (Figure 2). The island is thought to have formed *ca.* 4.5 ka (Morton, 2008). Historically, the island was identified as two strandplain features connected by a relatively low-elevated 3 km spit, known simply as Ship Island (Otvos and Carter, 2008). The island has been bisected several times in modern history due to tropical cyclonic impacts and overwash in 1850, 1852, 1893, 1947, 1965, and again in 1969 (Schmid, 2003). The 1947 breach left a 1.75 km inlet starting west of the East Ship core (Otvos and Carter, 2008). Through natural aggradation, the island maintained its stability through these impacts, but the breach by Hurricane Camille did significant damage (Otvos and Carter, 2008 and Morton, 2008). The storm created a tidal inlet locally known as Camille Cut, which has since been a permanent feature of the island, giving rise to the names West and East Ship Island. Ship Island, throughout its history, has been vulnerable to breaching due to its low elevation and narrow barrier neck. The Ship Islands have experienced spit growth following breaching, and in some cases have almost closed the gap. By 1997, East Ship Island added roughly 2.0 km of spit growth toward West Ship, reducing Camille Cut down to about 1.0 km. However, Hurricane Georges (1998) negated much of the island's growth by adding a temporary breach and removing about 2.7 km of the spit. Hurricane Katrina eroded everything but East Ship's core, leaving the island about 1.5 km in length and 400 meters wide (Otvos and Carter, 2008; Otvos and Carter, 2013). Further, the island is dominated by relict dunes that have been formed through these cyclonic impacts. These dunes have become a prominent feature on East Ship Island, due to its low elevation and vulnerability to run-up and inundation overwash.

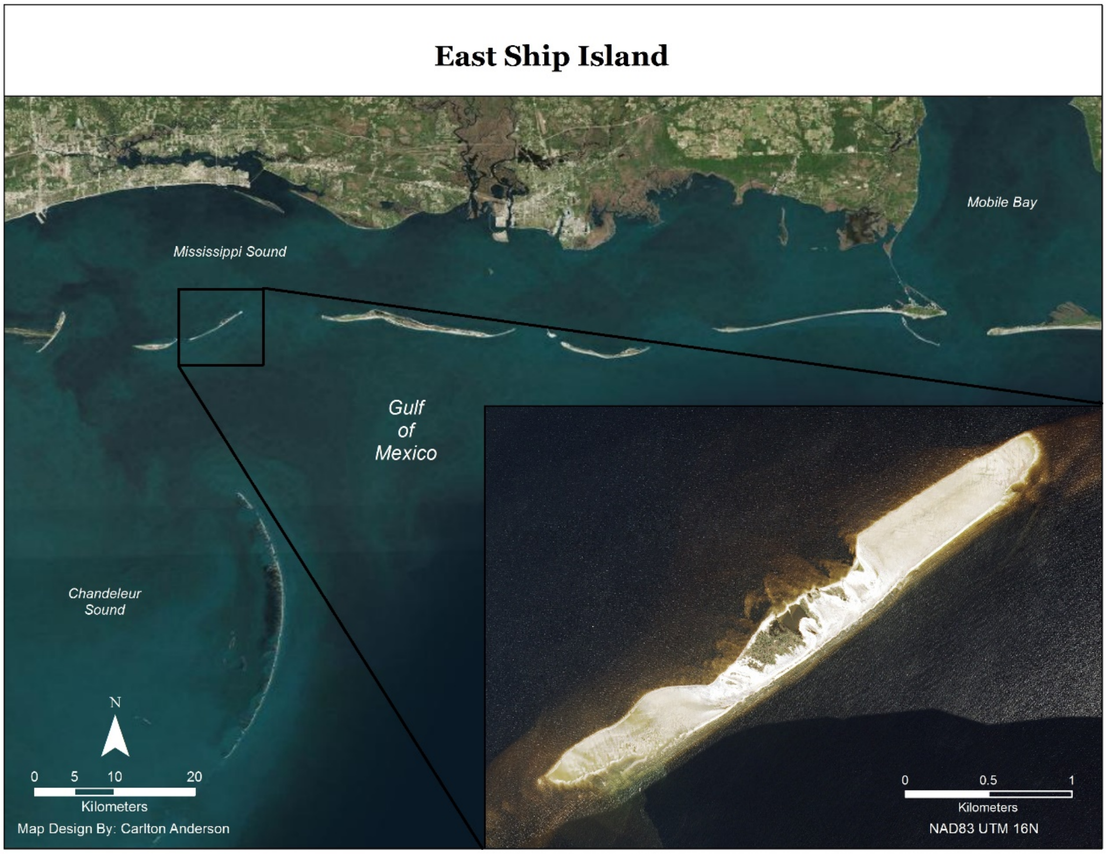


Figure 2. Aerial Imagery depicting the Mississippi and Alabama Gulf Coast along with the East Ship Island study area. Inset imagery was acquired in 2012.

As of 2012, East Ship Island was roughly 3.5 km in length, backed by a 16 km lagoon. The island has a central core, which has remained relatively intact through multiple tropical events, and has been historically the most stable portion of the island (Schmid, 2003). The core is characteristic of a freshwater pond, with muddy peat soils and relict dune ridges vegetated with species, such as beach morning glory, salt meadow cordgrass, marsh elder, saw palmetto, and establishing sand live oak. East and west spit growth out from the island core is characteristic mainly of beach grasses and algal flats (Schmid, 2003).

East Ship Island is currently managed by The National Park Service (NPS), Gulf Islands National Seashore (GUIS) (USACE, 2014).

Sand Island

There has been little attention to Sand Island, so the literature concerning this man-made island is deficient, leaving its formation and make-up to be relatively poorly understood. DA-10, locally known as Sand Island, located on the western side of the Pascagoula ship channel (30.224, -88.522), is about 1.7 km in length, and is composed mostly of quartz sand mixed with calcareous shell fragments (Figure 3).

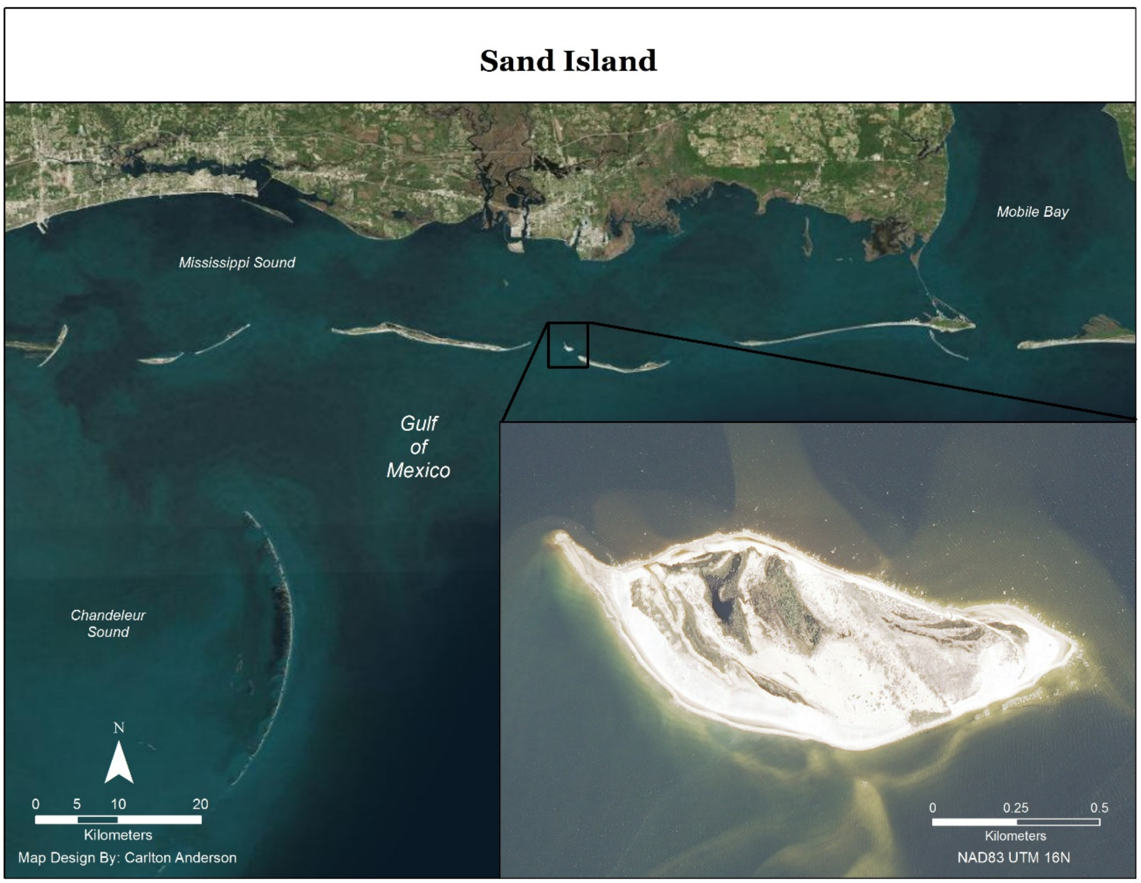


Figure 3. Aerial Imagery depicting Mississippi and Alabama Gulf coast along with the Sand Island study area. Inset imagery was acquired in 2012.

The island began formation in the 1960s from an underwater shoal created through the deposition of dredge spoil from the neighboring Pascagoula ship channel (Otvos and Carter, 2008). The emergence of Sand Island took place around 1971 with channel maintenance and the natural reworking of the ebb-tidal sediment, combined with littoral drift (Otvos and Carter, 2008). Since the emergence of the island, highly elevated east-west recurved and truncated beach ridges have been formed and reshaped by littoral drift and wave action (Otvos and Carter, 2013; Otvos and Carter, 2008). Presently the island has the highest elevation of the islands in the MSAL barrier chain. According to Otvos and Carter (2008), Sand Island helps to mitigate ebb-tidal sand loss. As with East Ship Island, Sand Island has a stable core characteristic of a freshwater pond and vegetated habitats. Vegetation includes species, such as wax myrtle, sea oat, gulf bluestream, and salt meadow cordgrass. In contrast to East Ship Island, Sand Island is not currently managed by NPS GUIS (USACE, 2014).

CHAPTER III

COMPARING HABITAT AND ELEVATION THROUGH REMOTE SENSING

Introduction

The use of remote sensing to understand and quantify vegetated habitats and geomorphic change on the MS-AL barrier island chain is not novel in the literature. As advancements have been made to the technology, its use as a scientific tool has become a great asset in providing the body of knowledge, a greater understanding of these dynamic coastal landforms. However, these studies have focused on longer temporal scales, and have failed to incorporate some of the human effects on the chain, such as using the technology to study man-made Sand Island. After Hurricane Katrina, major emphasis was placed on the restoration of the MS-AL barrier island chain (USACE, 2014). Further, following the blowout of the Macondo Well off the Louisiana coast (April 20, 2010), the need for remotely sensed data acquisitions at finer resolutions to track and recognize effects from oil slicks became essential (Kokaly, 2013). Many government and private contractors flew missions in the NGOM to suit research needs, widening the breadth of remotely sensed data in the region. The current availability of this data has allowed for a short temporal scale comparison study of vegetated habitats on the MS-AL barrier island chain. Additionally, the use of LIDAR at fine scale spatial resolutions have allowed for elevation studies.

For this study, a combination of remotely sensed imagery in the form of The National Agriculture Imagery Program (NAIP) collected in 2007, 2009, 2010, and 2012 was used to conduct a change detection of vegetated habitats on East Ship and Sand Island between 2007 and 2012. Supervised classification maps were produced based on habitat types derived from ground data acquired in 2010, to determine distribution and coverage of habitats. Further, LIDAR data acquired in 2012 was used to quantify elevation, volume, and relationships between elevation and vegetation on East Ship and Sand Islands. By using these data acquisitions, a short-term comparison spanning only five years was made on East Ship and Sand Island.

Materials and Methods

Ground Sampling

In 2010, the Gulf Coast Geospatial Center (GCGC) conducted a field vegetation survey for the MS-AL barrier island chain. Ground surveyed data were taken using randomly selected points at a mean density of one point per 6 ha of island area. The method was based on Lucas and Carter's (2008) previous study which utilized similar sampling densities, but used line transects as opposed to random point sampling. Sample points were positioned randomly using ENVI v4.3 software from SPOT-5, 10-m ground sampling distance (GSD) multispectral coverage (April-July 2010 image acquisitions, North American Data Purchase, USGS EROS Data Center, Sioux Falls, SD). Geographic centers were then visited, using a Trimble Geoexplorer 6000. If a sample point fell in a body of water, it was moved to the nearest above-water area. A range pole with alternating 0.3 m orange and white segments was then planted in the ground, and notes were made concerning primary and secondary vegetation species in the immediate area. Additionally, photographs were taken at each point using a Nikon model D-60 SLR with a Nikon 18-55 mm f/3.5-5.6G VR AF-S DX lens, set at 18 mm to achieve the widest field-of-view. Photographs were taken clockwise at magnetic compass headings of 0°, 90°, 180°, and 270°, to give a full representation of habitat in the area. Habitat classifications were then made through the visual inspection of photographs and documented primary and secondary species. The classification scheme was based on those used in the Mississippi Natural Heritage Program 2006 (Mississippi Natural Heritage Program, 2006).

A geodatabase was constructed in ArcGIS v10.1 to house all sample point information. All point data were projected in the North American Datum 1983 (NAD83) 16 North. Attribute fields for point data included: site identification number, site visitation date, time, horizontal precision, geographic coordinates of the site, primary species, secondary species, general notes pertaining to the site, and habitat classification type. Sample site photographs were attached as binary large objects in the geodatabase for data management and ease of use.

NAIP Imagery and Calibration of Imagery

United States Department of Agriculture (USDA) NAIP imagery was used in this study because it is collected every two years with the intent of providing current information of agricultural conditions in a given area (USDA-FSA-APFO, 2012). NAIP did not collect imagery over the MS-AL barrier island chain until 2007. Thus, the imagery used was for the years 2007, 2009, 2010, and 2012. Imagery was taken using a Cessna Conquest aircraft mounted with an Intergraph Digital Mapping Camera calibrated by the manufacturer. All acquired imagery had accompanying global positioning systems (GPS) and inertial measurement unit data (USDA-FSA-APFO, 2012). Starting in 2012, for the state of Mississippi, NAIP imagery consisted of four bands, with three in the visible spectrum (blue: 400-580 nm, green: 500-650 nm and red: 590-675 nm) and one in the near infrared (675-850 nm). However, prior to 2012 NAIP did not collect data in the near infrared band for the state of Mississippi, thus this study employs the use of the blue, green, and red visible bands for all analysis to ensure image comparability. The imagery has a GSD of 1 m, pixels contain a brightness value (BV) based on 8-bit gray-scale binning (0-255), and is projected in NAD83 16 North (USDA-FSA-APFO, 2012). Data acquisition dates for East Ship Island were: August 2007, 2009, 2010, and September 2012, and acquisitions for Sand Island were: August 2007, June 2009, May 2010 and September 2012.

All NAIP imagery was post-processed by the data collector, and has been quality assured and controlled before release to the USDA. Post-processing included the use of digital camera Intergraph Post Processing Software and SURDEX software to remove bidirectional reflectance, vignetting, and other trends (USDA-FSA-APFO, 2012). After initially downloading imagery from the USDA, sub-setting was performed in ENVI v4.8, to include only the island area-of-interest in each image for faster data processing.

Several image calibration methods were used in order to conduct change detections for East Ship and Sand Island. An image-to-image geometric registration was performed for all East Ship and Sand Island imagery. The base image chosen was 2010 for each island, due to ground data collection in that year. Images for 2007, 2009, and 2012 were georectified to 2010 with no less than 10 ground control points (GCP) for each image with a total $RMS_{error} < 0.5$, as per registration methods outlined by Jensen (2005). Due to the lack of anthropogenic features and hard targets on both islands, GCPs consisted of individual patches of vegetation that remained stable and identifiable in each image. BVs for each band (blue, green, and red) for 2007, 2009, and 2012 images were stretched to match 2010 BV data ranges to correct for BV intensity differences, and to provide a base line for calibration to surface percent reflectance values.

Image BVs were standardized to known surface percent reflectance values using the empirical line method. The method calibrates remotely sensed data to match that of known *in situ* surface values by employing a linear regression for each band to assign a reflectance value for each pixel (Jensen, 2005). Using the assumption that island beach bare sand surface reflectance should stay consistent year after year, Regions-of-Interest (ROI) consisting of 3,000 bare sand pixels were selected in each image to provide sample data for the regression. *In situ* data used for the calibration was bare beach sand, recorded using a portable spectroradiometer (ASD-FS) on Horn Island.

Supervised Classification of Habitats

The supervised classification method used in this study was the maximum likelihood (ML), due to its wide acceptance, while providing the greatest amount of accuracy in comparison to other classifications (Jensen, 2005; Lucas and Carter, 2008; Peneva, Griffith, and Carter, 2008). The ML classifier determines a pixels probability of belonging to one of any certain classes that is predefined by the user by assuming the training data statistics in each band are normally distributed, and the variability in each defined ROI is accounted for (Jensen, 2005; Lucas and Carter, 2008; Peneva, Griffith, and Carter, 2008).

ML classifications were created for East Ship and Sand Island initially for 2010 due to the ground survey taking place that same year. The habitat classes used for East Ship Island were algal flat, bare sand, beach dune herbland, marsh shrubland, and water. (Figure 4). The same classes were used for Sand Island with the exception of algal flat. Sampled pixel data were generated from 2010 ground survey GPS locations with habitat type information and photographs attached. Additionally, training data pixels were selected in 1 m ROI increments based on estimations from the range pole in the field photographs.

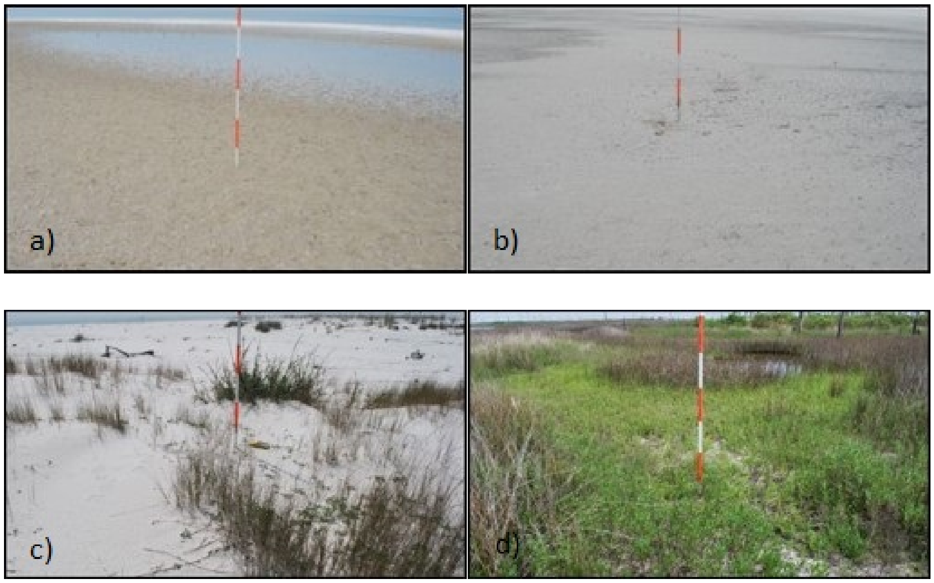


Figure 4. Habitat classes used for all ML classifications: a) algal flat, b) bare sand, c) beach dune herbland, and d) marsh shrubland. The water class is not shown. Photos by Carlton Anderson.

Further, masks were created in ArcGIS v10.1 by digitizing shorelines (1:600 scale) for each island image, ensuring classification of only land areas. Shorelines were interpreted by the discernable wet-to-dry sand interface, allowing for tidal fluctuations between image dates (Boak and Turner, 2005). Sample pixel data were selected in 1 m increments for 2007, 2009, and 2012 images, based on mean surface percent reflectance threshold values from each habitat in the 2010 ML (Appendix A). Post-classification reports were generated, consisting of a confusion matrix to determine the overall accuracies, coefficient of agreement (K_{hat}), and errors of commission and omission (Jensen, 2005). Commission errors represented the percentage of pixels that are assigned to a class, while belonging to another class. These errors apply to the training data used in the ML classification. Omission errors were represented by the percentage of pixels belonging to a class that has not been classified as such by the reference or sampled data (Boschetti, Flasse, and Brivio, 2004).

Change Detection

A post-classification change detection was used in this study, as it is the most widely used and understood method. Two classification maps were compared on a pixel-by-pixel basis using Geographic Information Systems (GIS) based raster algorithms in ENVI v4.8 to produce a change detection matrix (Jensen, 2005; Singh, 1989). Classifications assign pixels a digital number for their respective habitats; as classifications are stacked the algorithm assigns pixels a new value based on change or no change. Special attention was given to ensure proper image registration and the overall accuracies of the classifications used in a post-classification change detections, as errors in both maps would affect final output of the change detection (Jensen, 2005). Change detections were performed for both East Ship and Sand Island, investigating 2007-2009, 2009-2010, 2010-2012, and 2007-2012.

Elevation Analysis

Lidar data was post-processed, and DTM models of East Ship and Sand Island for 2012 were constructed in ArcGIS v10.1 for elevation analysis. Complete LIDAR coverage of the MS-AL barrier island chain was collected in October of 2012 by the Galileo Group, using a LEICA ALS 60 sensor mounted in a twin engine otter aircraft. The flight consisted of 48 lines flown at an above ground level altitude of 2,611 m, with a speed of 57 m/s. The LIDAR has a GSD of 1 m (Galileo Group, 2012). LIDAR was post-processed by the provider using EarthEye software. Horizontal accuracies of ± 4 cm and vertical accuracies of ± 12 cm were noted in the combined separation report graphs included in the delivered product (Galileo Group, 2012). LIDAR data were initially processed and delivered by the collector in laser file exchange format (LAS) v1.2, following criteria set by the American Society for Photogrammetry and Remote Sensing Board (ASPRS, 2008). LAS files were selected for East Ship and Sand Island by ensuring full island coverage based on a polygon tile scheme projected in NAD83 16 North. Each island consisted of six LAS files. LAS files were initially filtered to remove erroneous noise by extracting values above 50 m in elevation, using LAStools software. Point clouds for the data were made by filtering all points not classified as 2 (bare earth). Elevation rasters were then produced using the mean elevation of all bare earth points within a 1 m GSD; this generally consisted of 0 to 3 returns, depending on the density of vegetation. A neighborhood raster calculator function was used to interpolate elevation rasters to produce a smooth surface without data voids by using the mean of a 5x5 moving window where areas of "no data" were assigned values based on the mean elevation within the window. This method was chosen to mimic the collection of the NAIP imagery as closely as possible. A total of three iterations had to be performed to fill data voids in DTM rasters. Elevation rasters were then clipped using digitized shorelines from the ML mask to ensure island elevation analysis above the discernible tidal interface. DTM rasters were projected into NAD83 16 North to ensure proper habitat elevation sampling from the 2012 ML classifications. Total volume was computed from the surface volume ArcGIS v10.1 geoprocessing tool.

Results

East Ship Island ML Classifications

Due to spectral similarities between algal flat and beach dune herbland on East Ship Island, separate classifications for the eastern end and core sections of the island were made. These classifications were mosaicked to produce a single classification map for each year. Overall accuracies for individual ML classifications were better than expected, ranging mainly from 95.3% – 99%. One outlier did occur for an east end classification, being 82% accurate. However, this was limited to one end of the island in 2010, and was confirmed to be accurately classed from the ground survey photos. The K_{hat} for the classifications fell in a high range of 0.93-0.97 (Appendix A). Errors of commission and omission were generally limited to misclassification of bare sand pixels classed as beach dune herbland or algal flat classed as bare sand.

In 2007 East Ship Island had a total land area of 56.6 ha, with most of that confined to the island's central core. An elongated spit resembling a lobster claw made up the northeast section of the island (Figure 5). Algal flats were mainly confined to the northeast spit, with other habitats located in the central core of the island. By 2009 the island added ~17.5 ha, resulting in a total land area of ~74 ha. Most of the addition was to the northeast and southeast sections of the island through spit development (Figure 6). Although the overall shape of the island remained stable, the island's total land area was reduced roughly 3 ha from 2009 – 2010 (Figure 7). An increase of ~25 ha to the island's total land area occurred from 2010 – 2012. This included the addition of a newly formed southeast spit with developing habitat (Figure 8). Tables 1 and 2 show East Ship Island's habitat coverage for 2007, 2009, 2010, and 2012.

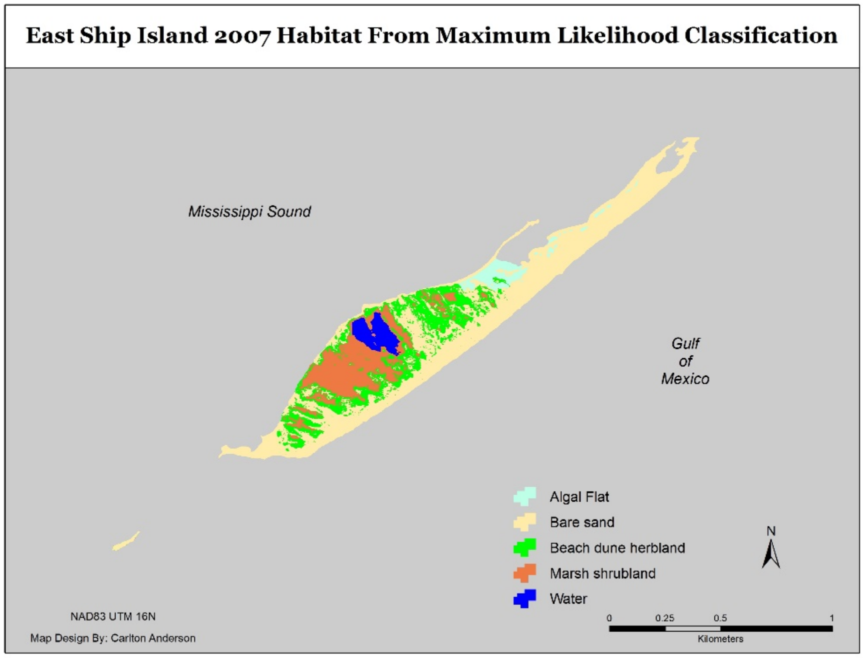


Figure 5. East Ship Island Maximum Likelihood classification for 2007. Beach dune herbland and marsh shrubland habitats dominate the island's central core.

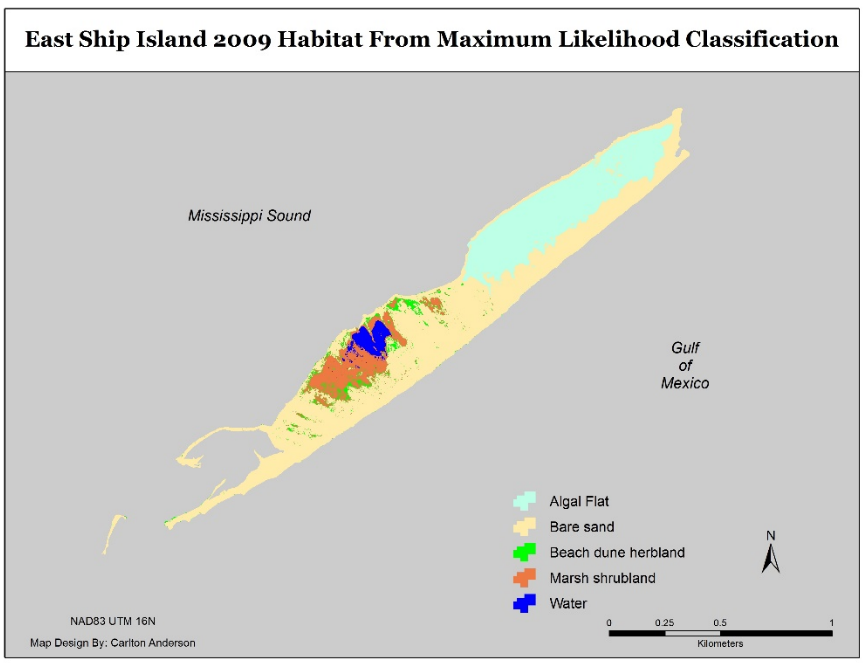


Figure 6. East Ship Island Maximum Likelihood classification for 2009. Northeast spit growth added ~17.5 ha of land area between 2007 and 2009, leading to major growth in algal flat. The beach dune herbland class was also reduced considerably from its 2007 total land area.

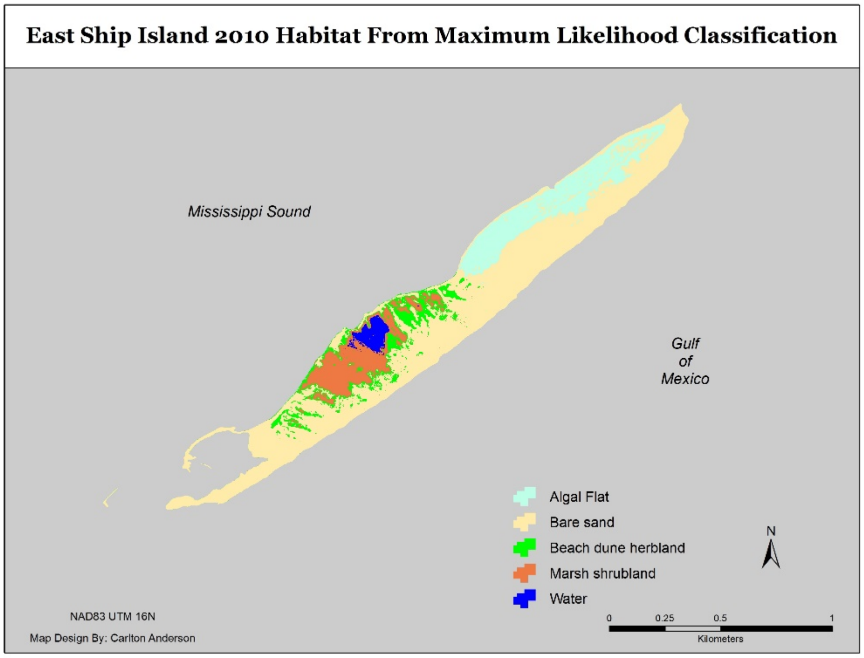


Figure 7. East Ship Island Maximum Likelihood classification for 2010. Reductions in the algal flat class can be seen between the 2009 and 2010 ML classification. Further, the expansion of the beach dune herbland habitat can be seen.

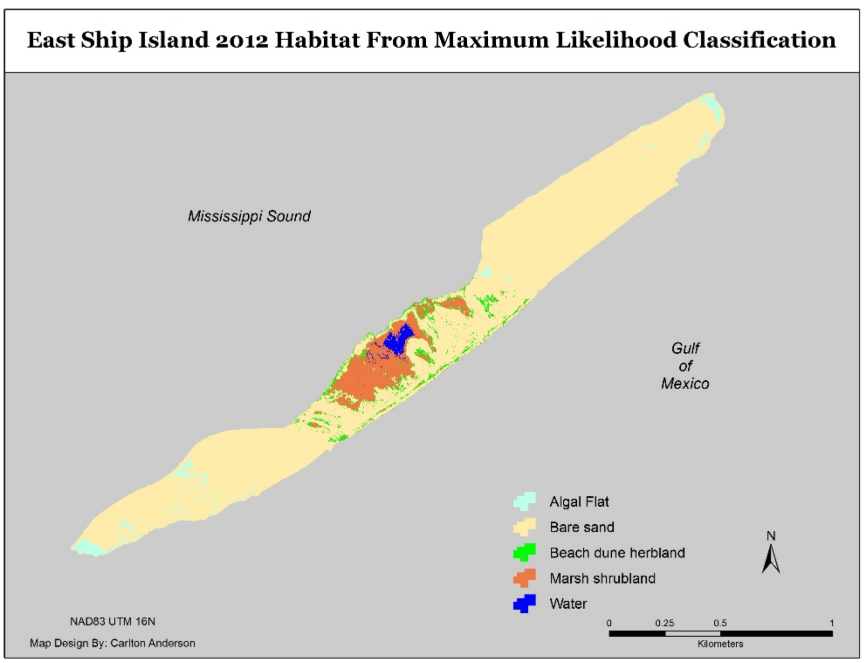


Figure 8. East Ship Island Maximum Likelihood classification for 2012. Major reductions in algal flat and beach dune herbland are discernible between the 2010 and 2012 ML classification. Northeast and southeast spit accretion led to the addition of ~25 ha of land area between 2010 and 2012.

Table 1

East Ship Island Total Projected Land Area in Hectares

Year	Algal flat	Bare sand	Beach dune herbland	Marsh shrubland	Water	Total
2007	2.31	31.50	10.64	9.96	2.26	56.67
2009	20.78	43.11	1.98	6.61	1.73	74.21
2010	11.96	44.67	5.55	7.43	1.58	71.20
2012	2.98	81.15	2.66	8.30	0.99	96.08

Table 2

East Ship Island Percentage of Total Projected Land Area

Year	Algal flat	Bare sand	Beach dune herbland	Marsh shrubland	Water	Total
2007	4.07	55.59	18.78	17.57	3.99	100.00
2009	28.00	58.10	2.67	8.90	2.33	100.00
2010	16.80	62.75	7.79	10.44	2.23	100.00
2012	3.11	84.46	2.77	8.63	1.03	100.00

East Ship Island Change Detections

Change detections for East Ship Island are reported as the total number of pixels (1 m) and total land area (ha) a given habitat has changed or remained stable between classifications. Further percentages are reported to illustrate change between initial and final states of habitat in the classifications (Appendix B). Change detections conducted for East Ship had major fluctuations mainly in the algal flat, beach dune herbland and bare sand habitats. The biggest habitat changes between 2007 and 2009 were in the beach dune herbland and algal flat classes. Beach dune herbland, had 86% (9 ha) of its total land area change to bare sand. Only 6% of beach dune herbland's total land area remained in 2009. Algal flat had 68% (1.5 ha) of its total land area change to bare sand. However, the class did increase its overall land area by 800% (18 ha). Marsh shrubland

and water also experienced some changes from 2007 – 2009, with small portions of their habitats changing to bare sand.

Changes from 2009 – 2010 were not as drastic as they were between 2007 and 2009. Changes were confined mainly to the algal flat and beach dune herbland classes. Just under half of the algal flat (8.5 ha) changed to bare sand, while the remaining portion of the habitat was stable. Beach dune herbland had ~4 ha of growth from bare sand and ~0.4 ha from marsh shrubland. The water class had ~0.3 ha change to marsh shrubland. Major changes occurred again between 2010 and 2012. These changes affected nearly all habitats on East Ship Island. The algal flat class had the largest change with 98% (11 ha) of its total land area changing to bare sand. Beach dune herbland also had a reduction in total land area of 61% (3 ha) to bare sand. Marsh shrubland remained fairly stable and had the smallest losses to bare sand. Additionally, water lost 42% (.6 ha) of its total area to marsh shrubland.

Similar trends in habitat change were noted through the investigation of the full temporal scale of classifications from 2007 – 2012. Marsh shrubland and water were the most stable habitats. Most of the algal flat present in 2007 was changed to bare sand by 2012. Beach dune herbland had 73% (8 ha) change to bare sand, with another 10% (1 ha) changing to marsh shrubland. Only 10% (1 ha) of beach dune herbland from 2007 remained through five years. Although the changes were relatively small, marsh shrubland changed mainly to bare sand and beach dune herbland from 2007 – 2012. Most of the water habitat changes were to bare sand and marsh shrubland.

East Ship Island Elevation Analysis

The 2012 DTM for East Ship Island reported a high elevation of 4.5 m and a low of -0.06 m. The presence of several overwash lobes and the island's main freshwater pond can be noted from the DTM (Figure 9). Water and algal flat had the lowest mean elevation of all habitats on the island with 0.54 m and 0.61 m respectively. Bare sand had a slightly higher mean elevation of 0.9 m. Marsh shrubland and beach dune herbland had the highest mean elevations with 1.39 m and 1.41 m respectively. Bare sand had the highest range of elevation (-0.06 m – 4.5 m). Beach dune herbland and marsh shrubland showed similar ranges of elevation with a ~3.5 m difference between low and high. Algal flat had the smallest range of elevation (-0.05 m – 1.48 m). The mean and ranges of elevations represent the total population as every pixel from the 2012 ML classification was sampled from the DTM (Table 3). Further, the total volume for East Ship Island was 961,425.11 m^3.

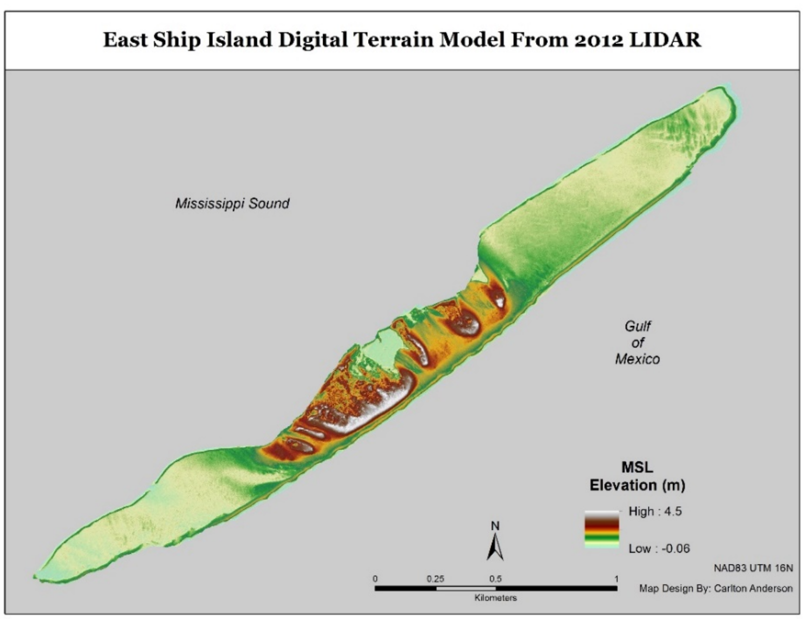


Figure 9. Digital terrain model for East Ship Island showing the island's high and low elevations. The presence of several overwash channels, lobes, and blowouts can be seen in and around areas of high elevated recurved dunes.

Table 3

Elevation for Habitats on East Ship Island in 2012

	Algal Flat	Bare sand	Beach dune herbland	Marsh shrubland	Water
Pixel count	2975	809528	26500	82698	9906
Minimum elevation (m)	-0.05	-0.06	0.11	0.13	0.14
Maximum elevation (m)	1.48	4.5	3.62	3.62	2.82
Mean elevation (m)	0.61	0.90	1.41	1.39	0.54

Sand Island ML Classifications

Classifications for Sand Island produced similar results to those for East Ship Island. Overall accuracies ranged from 96% – 99%, with high K_{hat} ranges of 0.95 – 0.99 for all classifications (Appendix C). However, separate classifications were not needed for each image of Sand Island, as the algal flat class is not present on the island. Commission and Omission errors were minimal and concentrated in the bare sand and beach dune herbland classes. Upon final inspection of initial classifications, it was found some areas of tidally influenced shorelines were classified as beach dune herbland, but through image and ground survey inspection it was found these areas were wet bare sand. They were manually classified as bare sand for the final ML classifications.

In 2007 Sand Island had a total land area of ~51 ha, was elongated in shape, and had one prominent spit on western shore. The island vegetation in 2007 consisted of mostly beach dune herbland habitat, with a discernible central core of marsh shrubland and water habitats (Figure 10). By 2009 only ~1 ha of total land area was added to Sand Island, and its overall shape changed slightly from 2007, through the reworking of its western spit (Figure 11). Between 2009 and 2010, ~16 ha of growth occurred, giving the island a total land area of ~68 ha in 2010 (Tables 4 and 5). Further, the island was still dominated by beach dune herbland vegetation, and had become semi-ovate in shape with two protruding spits on its western shore (Figure 12). By 2012, marsh shrubland expanded into other portions of the island. The total land area was also reduced by ~11 ha, and the two western spits were reworked into one feature (Figure 13).

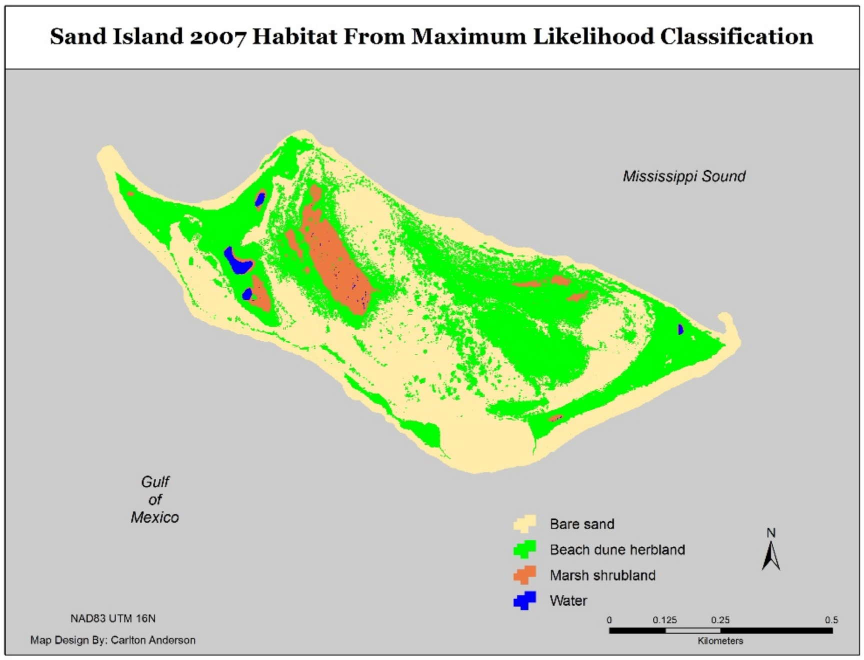


Figure 10. Sand Island Maximum Likelihood classification for 2007. Elongated in shape, the overall land area of Sand Island in 2007 was ~51 ha. The island was dominated by beach dune herbland, and had a central core consisting of marsh shrubland complete with freshwater habitats.

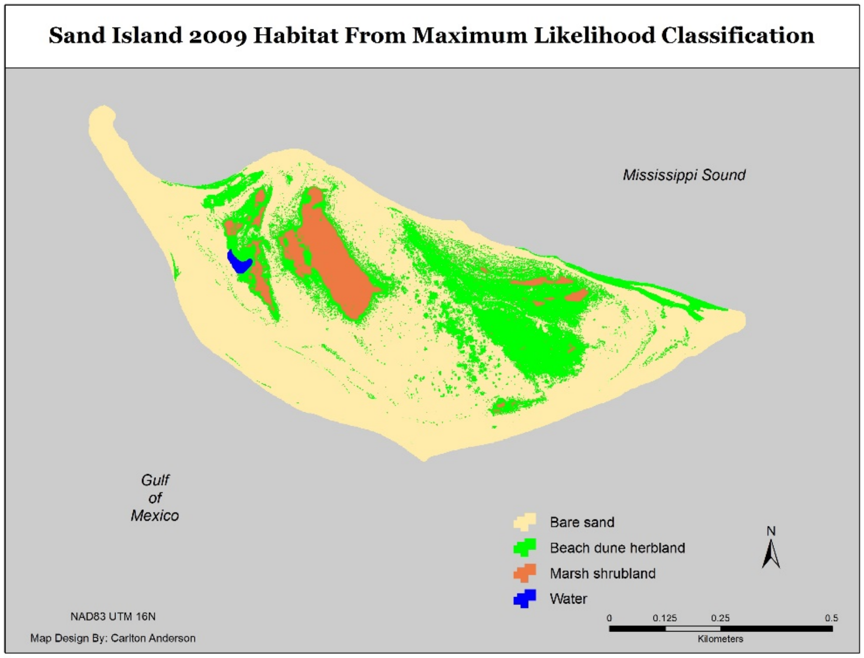


Figure 11. Sand Island Maximum Likelihood classification for 2009. Total island land area was increased by ~1 ha from 2007 – 2009, with the reworking of the island's south shore and northwest spit. Further, major reductions to the beach dune herbland class can be seen, with losses south and east of the island core.

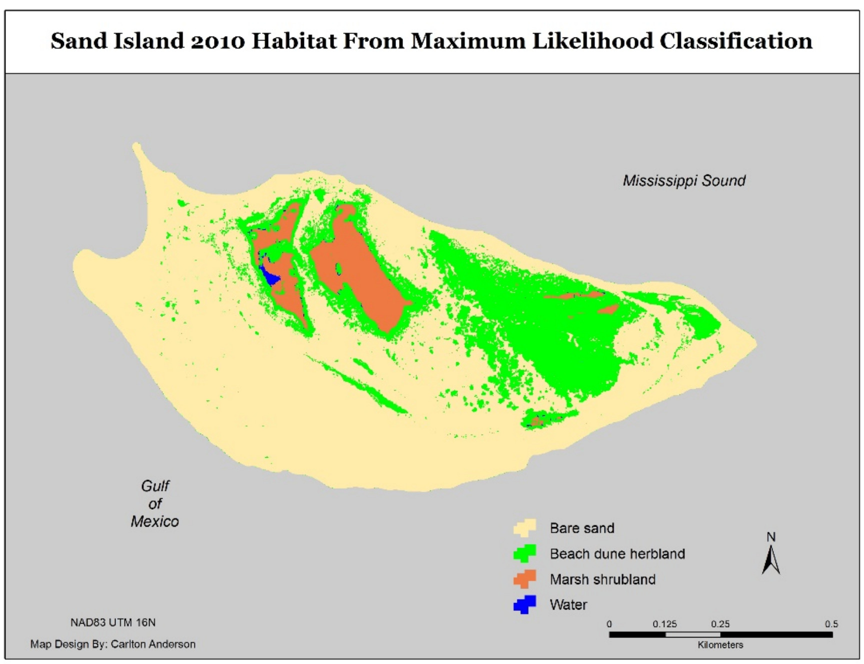


Figure 12. Sand Island Maximum Likelihood classification for 2010. Still dominated by beach dune herbland in 2009, Sand Island's land area increased to ~68 ha and became semi-ovate in shape with two spit features on the island's northwest shore.

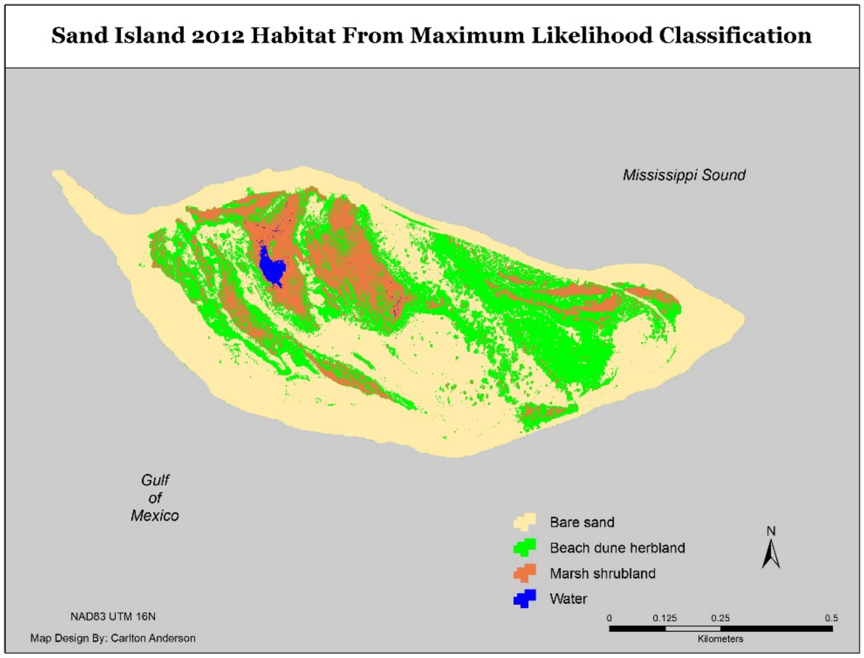


Figure 13. Sand Island Maximum Likelihood classification for 2012. Total land area was reduced by ~11 ha, mainly on the southeast shore. However, a major increase to the marsh shrubland habitat can be seen from 2010 – 2012.

Table 4

Sand Island Total Projected Land Area in Hectares

Year	Bare sand	Beach dune herbland	Marsh shrubland	Water	Total
2007	27.60	21.10	2.74	0.29	51.73
2009	37.13	12.12	3.53	0.15	52.93
2010	49.29	15.02	4.04	0.14	68.49
2012	33.15	15.86	8.36	0.32	57.68

Table 5

Sand Island Percentage of Total Projected Land Area

Year	Bare sand	Beach dune herbland	Marsh shrubland	Water	Total
2007	53.36	40.79	5.29	0.57	100.00
2009	70.15	22.90	6.68	0.28	100.00
2010	71.96	21.94	5.89	0.21	100.00
2012	57.46	27.50	14.49	0.55	100.00

Sand Island Change Detections

Change detections for Sand Island are reported in the same manner as those for East Ship Island (Appendix D). From 2007 – 2009 the beach dune herbland and water habitats had the most changes while marsh shrubland remained fairly stable. Beach dune herbland had ~21 ha of total land area in 2007. Just under half of beach dune herbland (9.5 ha) changed to bare sand. Water had 25% (.07 ha) of its .29 ha change to bare sand by 2009. Further, water was lost to marsh shrubland and beach dune herbland, reducing its total land area by half. Most of the changes were minimal to marsh shrubland, with some changes to beach dune herbland and water.

The least amount of habitat change occurred from 2009 – 2010. All habitats were stable, and some experienced slight growth from bare sand. The effects were mainly to beach dune herbland, with increases in habitat size. The bare sand habitat was reduced to 13% (4.5 ha) of its 2009 land area (37 ha) to beach dune herbland. Marsh shrubland also had 13% (.5 ha) of its habitat change to beach dune herbland. Most of the changes in the water habitat were to marsh shrubland. Changes were extreme for all habitats on Sand Island between 2010 and 2012. Bare sand had a 12% (6 ha) loss in total land area to beach dune herbland and 4% (2 ha) to marsh shrubland. Further, the overall land area of the island was decreased, affecting bare sand the most. While beach dune herbland did have a net gain of .8 ha of land area, it lost 19% (9 ha) of its 2012 land area to marsh shrubland, with smaller portions changing to bare sand. Changes to the water habitat were small, with ~0.04 ha changing to marsh shrubland. Marsh shrubland had the biggest growth between 2010 and 2012, adding 4 ha of total land area.

Spanning five years from 2007 – 2012, the most notable changes were to the increase in marsh shrubland habitat, from its initial state of 2.7 ha to 8. 3 ha. Beach dune herbland transitioned 18% (.5 ha) of its habitat to marsh shrubland in five years. Bare sand had 15% (4 ha) of its habitat change to beach dune herbland. However, beach dune herbland had a net loss of 6 ha of total land area from 2007 – 2012. Bare sand has had overall growth from 2007 – 2012 with the addition of ~5.5 ha of total land area. The water habitat has stayed stable through the five year span, with a slight increase of .1 ha of total land area. Most of the changes in the water habitat were to marsh shrubland.

Sand Island Elevation Analysis

The DTM for Sand Island from the 2012 LIDAR indicated a high elevation of 9.34 m and a low of -0.28 m. Several high elongated dunes and other features, such as the island's inland pond, are identifiable in the DTM (Figure 14).

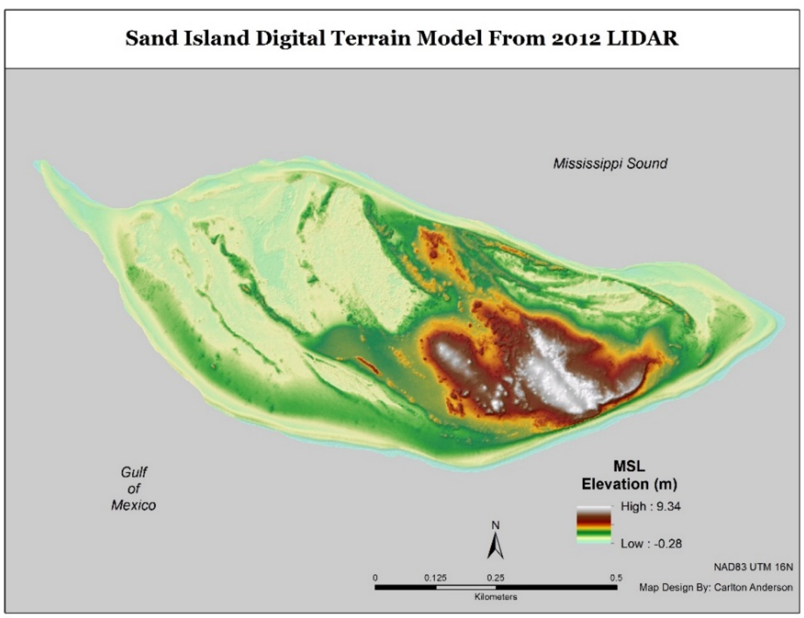


Figure 14. Digital terrain model for Sand Island showing the island's high and low elevations. Several dune ridges can be noted through the high elevations and steep topography along the island's northeast, southeast, and southwest shores.

Water and marsh shrubland habitats had the lowest mean elevations on Sand Island in 2012, with 0.75 m and 1.23 m, respectively. Bare sand had a mean elevation of 1.98 m and beach dune herbland was the highest at 2.37 m. Beach dune herbland also had the biggest range in elevation, with a minimum of .05 m and a high of 9.34. Bare sand and marsh shrubland exhibited similar elevation ranges of ~9.10 m, while water had the smallest range of 1.35 m between low and high (Table 6). As of 2012, the total volume for Sand Island was 1,302,782.91 m^3.

Table 6

Elevation for Habitats on Sand Island in 2012

	Algal flat	Bare sand	Beach dune herbland	Marsh shrubland	Water
Pixel count	Null	330469	158164	83168	3137
Minimum elevation (m)	Null	-0.28	0.05	0.07	0.45
Maximum elevation (m)	Null	8.95	9.34	9.17	1.8
Mean elevation (m)	Null	1.98	2.37	1.23	0.75

Discussion

Examining elevation, habitat type, coverage, distribution, and change for East Ship and Sand Island led to finding very similar attributes between these two small islands. Both islands exhibited very similar traits in their types of vegetation, change in habitats, and geomorphic features found. When determining habitat types for use in ML classifications, it was found these two islands share similar species make-up. Species such as sea oat, beach morning glory, and gulf bluestream were indicative of the beach dune herbland class. The same was true in the marsh shrubland class with grasses such as saltmeadow and smooth cordgrass, as well as the marsh elder and wax myrtle. The only exception was the presence of algal flats on East Ship Island. Sand Island currently lacks dominant climax woody species that are found on the other islands in the chain such as slash pine and sand live oak. While East Ship Island does have an establishing patch of sand live oak, its coverage and current succession was ineffective in creating a woodland class. Climax species for East Ship and Sand Island include woody shrubs, such as the marsh elder and wax myrtle, making marsh shrubland the current climax community on both islands. As Schneider and Kruse (2003) proposed, the presence of a freshwater lens can indicate the type of vegetation found and overall island stability. These two islands have a freshwater pond in their central core, indicating the existence of a freshwater lens.

Bare sand on both islands lack surface vegetation; however, it provides the elevation and parent material needed for the initial pioneering of grass species that eventually transition to shrubs and various types of trees found in woodland habitats (Maun, 2009). It has been postulated that elevation is the key determining factor in the vegetation found on a barrier island (Lucas and Carter, 2010). While bare sand has a broad range of elevation on both islands, it is also very unstable, allowing for the transition to various habitats. Bare sand transitioned mainly to and from the algal flat and beach dune herbland classes through fluvial and aeolian burial of vegetation. Barrier islands are dynamic landforms with alterations occurring to their elevation on a regular basis, ultimately affecting their habitats. Hurricanes and tropical storms are the major cause of sudden and extreme changes to the MS-AL barrier island chain (Lucas and Carter, 2010; Morton, 2008). From 2007 – 2012 two tropical events effected both East Ship and Sand Island with sustained winds > 20 m/s (Berg, 2012; Beven and Kimberlain, 2009). Hurricanes Gustav (September 1, 2008) and Isaac (August 29, 2012) both passed to the west of the MS-AL barrier island chain on similar northwest tracks, making landfall near the mouth of the Mississippi River. These two events had the most profound effects on habitat during the time span of this study.

According to Beven and Kimberlain (2009), storm tides for Hurricane Gustav were 2.03 m at Point Cadent in Biloxi, Mississippi (30.42N, 89.83W) and 2 m at the Port of Pascagoula (30.35N, 88.51W). Wind gusts of ~30 m/s were also reported in these areas during the storm. Absent on Sand Island, the algal flat habitat on East Ship Island was affected by Gustav with major growth. From 2007 to 2009, ~18 ha of projected land area was added to the class. Run-up overwash from Gustav's shore normal tidal surge aided in creation of a large intertidal zone, extending from the island's core down the entire length of the northeast spit. Due to the low mean elevation of beach dune herbland, major transitions occurred in the habitat, with losses of total projected land area by as much as 90% from 2007-2009. Sand Island also experienced about half of its beach dune herbland transitioning to bare sand following Gustav. These transitions were due to storm tides not completely overwashing fore and back dunes, leaving vegetation buried. The storm also caused a foredune blowout responsible for the partial filling of East Ship Island's freshwater pond (Figure 15). While losses did occur in the marsh shrubland class on East Ship Island, they were not as profound as they were in the other classes. This was more than likely due to protection from the fore and back dunes. The impacts from Gustav on East Ship led to the addition of total land area, although reducing habitat size and coverage. The effects on Sand Island were mainly to the lower dune vegetation. Some spit reworking and land growth on the island's southeast side were visually identifiable through the NAIP imagery.

Figure 15. East Ship Island pre-Gustav (2007) on the left and post-Gustav (2009) on the right. A foredune blowout with an overwash lobe extending in the island's freshwater pond can be seen post-Gustav.

Smaller changes were seen from 2009 – 2010 on both islands. The building of a small berm on the lagoonal side of East Ship's major intertidal zone allowed sediment deposition to reduce the algal flat habitat ~10 ha. Reestablishment of beach dune herbland took place between 2009 and 2010. Both islands had bare sand transition to beach dune herbland by ~4 ha. Marsh shrubland also increased on East Ship Island, with small transitions from beach dune herbland, indicating succession of beach grasses to meadow grasses. In addition to dune building, geomorphic changes on East Ship Island, identifiable on imagery, were mainly due to in place narrowing likely caused by increased fetch from the northwest. Reports from dredging activities in the Mississippi Sound by the USACE are not easily accessible, and in some cases are not made public (Parsons and Swafford, 2012). Nevertheless, a major addition of bare sand took place on Sand Island between 2009 and 2010, likely the result of artificial deposition from dredge spoil.

In 2012, Hurricane Isaac produced storm tides of 2 m at Point Cadet and 1.81 m at the Port of Pascagoula (Berg, 2013). Wind speeds were slightly higher than Gustav's at these sites, with gusts > 32m/s. Hurricane Isaac was very similar to Gustav in respect to wind energies, storm tides, trajectory, and total projected area, but Isaac's forward speed was hindered due to a mid-level blocking ridge northwest of the storm (Berg, 2013; Beven and Kimberlain, 2009). The slower forward speed of Isaac led to longer periods of storm tide run-up overwash and high southeast wind and wave fetch, shaping both islands geomorphically and ecologically. A major addition of ~23 ha of bare sand was added to East Ship's southeast spit, completely reshaping the island, and skipping the algal flat successional phase altogether. Additionally, the majority of algal flat on the northeast spit transitioned to bare sand through overwashing and burial. The higher mean elevation of beach dune herbland on Sand Island allowed for the habitat to remain relatively stable during Isaac (Figure 16). This was not the case on East Ship Island, as nearly all beach dune herbland reestablishment post-Gustav was eliminated by Isaac. Several identifiable overwash lobes and channels can be seen on East Ship's DTM as a result of Isaac and past storms. Figure 17 shows a surge inundation model of East Ship Island based on the reported 2 m storm tide during Isaac to illustrate the coverage and distribution of surge in relation to beach dune herbland.

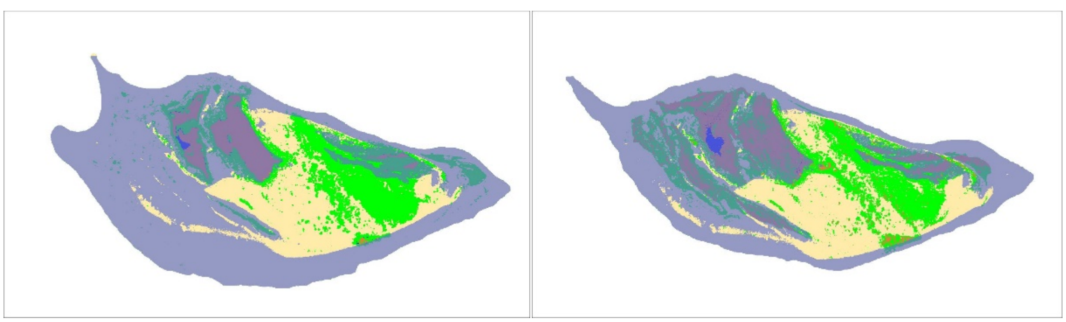


Figure 16. Sand Island inundation model based on Hurricane Isaac's storm tide (1.8 m) at the Pascagoula Ship Channel. The depiction on the left shows inundation based on the ML classification from 2010. Depiction on the right shows inundation based on the ML classification from 2012. Beach dune herbland highlighted in green remained stable during Isaac due to the higher elevations of the habitat. Land loss on the island's southwest shore can also be distinguished between the depictions.

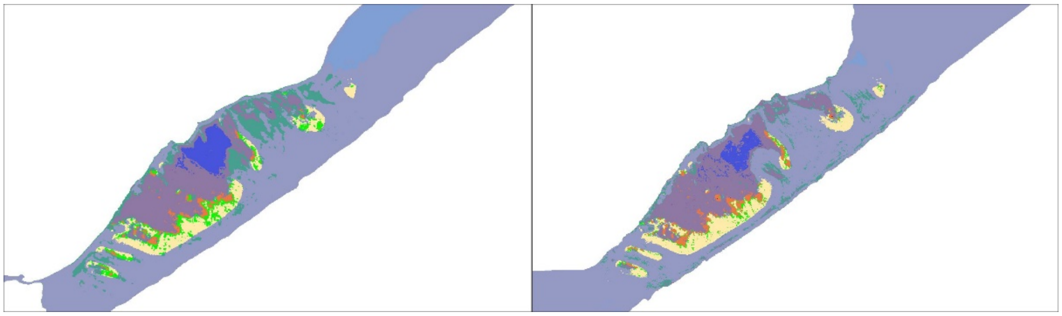


Figure 17. East Ship Island inundation model based on Hurricane Isaac's storm tide (2.0 m) at Point Cadet in Biloxi, Mississippi. The depiction on the left shows inundation of the island's core based on the ML classification from 2010. Depiction on the right shows inundation of the island's core based on the ML classification from 2012. Beach dune herbland and algal flat highlighted in green and blue, respectively, experienced major changes during Isaac due to low elevations and overwash. Further, an addition to the overwash lobe created by Gustav in the island's freshwater pond can be seen.

Wind, wave, and surge energies were not shore-normal on Sand Island as they were for East Ship Island during Isaac, resulting in ~11 ha of land loss, as opposed to land gain. Depths on the average of 3 m flank Sand Island to the south and southwest falling steeply to about 5 m – 6 m to the west and northwest of the island (NOAA, 2012b). Eroded sediment from the island was most likely lost due to the sharp decline in bathymetry. Depths in Camille Cut are on the average of 1.5 m and are gently sloping (NOAA, 2012a). Further, sediment transport continues through Ship Island's eroded tidal inlet via littoral drift cell four (Cipriani and Stone, 2001). East Ship Island's land growth in 2012 could have been affected by the presence of the postulated littoral drift cell four and relatively shallow depths, allowing for sediment accretion.

CHAPTER IV

USING REPEAT PHOTOGRAPHY TO INTERPRET HABITAT CHANGE

Introduction

Repeat photography is, in essence, the re-photographing of a particular scene as it appeared from earlier photographs in the same location (Bass, 2004; Burton, Mitchell, and Cutter, 2011; Kull, 2005). Repeat photography as a field method for determining land change has been used by many researchers since the late 19th Century. It provides records of the physical landscape that are accurate and longer lasting than an observer's memory. Using the technique also provides for a cost effective, low invasive way of sampling areas that may be ecologically sensitive to other methods (Burton, Mitchell, and Cutter, 2011). Repeat photography can prove valuable in providing *in situ* data for use in conjunction with satellite or airborne remotely sensed images. There are some disadvantages of using the method, such as minimal accuracies for quantification of change, making the method mainly qualitative, which can lead to interpreter biases. Additionally, changes are generally only detectable through visual inspection of photographic pairs, leading to errors of omission (Burton, Mitchell, and Cutter, 2011). While there are some limitations and advantages to using the method for change detections of the physical landscape, it is widely accepted and used. It has been estimated through the literature that over 90% of repeat photography studies have involved geomorphic and ecological investigations (Kull, 2005). However, there is currently a lack of research using repeat photography methods on the MS-AL barrier island chain to illustrate landscape change.

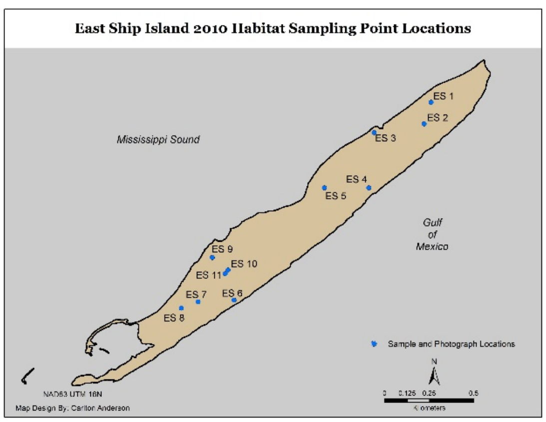
This study uses repeat photography to investigate ecological and geomorphic changes on East Ship and Sand Island from 2010 – 2014. Scene locations from 2010 for each island were revisited in 2014, collecting photographic and ecological data. In addition, a real-time-kinematic (RTK) survey was conducted at each location in 2014 to provide a better understanding of habitat elevation, and to establish a baseline for future repeat studies on these two islands. Qualitative and quantitative analyses were performed through the visual inspection and tabulation of change between photograph pairs. Repeat photography coupled with an RTK survey allowed for a short-term investigation of landscape change on these two dynamic barrier islands.

Materials and Methods

Ground and Real-Time-Kinematic Survey

A total of 11 point locations for East Ship Island and 10 for Sand Island from 2010 were revisited. Kull (2005) notes that one inherent problem in photo pair analysis is the inherent spatial biasing of scene selections. Through the clustering or over dispersal of samples, spatial biasing ultimately does not reflect the broader picture of landscape change for the study area (Kull, 2005). This problem was mitigated in this study by using 2010 sample points that were randomly selected at 1 point for every 6 ha of island total land area. Through two trips to each island in the fall of 2014, the same method was utilized as outlined in the ground sampling method in Chapter III of this thesis. The 2010 geodatabase was updated by adding attribute fields for the 2014 primary and secondary species, habitat type, and general notes concerning the sites. Photos from 2014 were also attached to each point location as binary large objects in the geodatabase for photo pair comparison. The best angle for each scene was captured by using the 2010 photos in the field with a range pole serving as a reference guide. Four scenes were duplicated at each point location on East Ship Island and Sand Island for a total of 44 and 40 photographic pairs respectively.

Elevation data was collected at each point location in 2014 using an RTK survey. The RTK system was equipped with a Trimble R-8 global navigation satellite system and Trimble TSC3 handheld data logger attached to a 2 m carbon fiber rod. The use of this system allowed for precise ellipsoidal, geoidal, and orthometric measurements with horizontal and vertical accuracies of ± 2 cm. All elevation data were collected in NAD83 Mississippi State Plane East using the reference GEOID12A model. In the field differential, corrections were made using the GCGC real-time-network of over 50 continuously operating reference stations throughout Mississippi. Figure 18 shows the sample point locations for photographic pairs and elevation on East Ship and Sand Island.



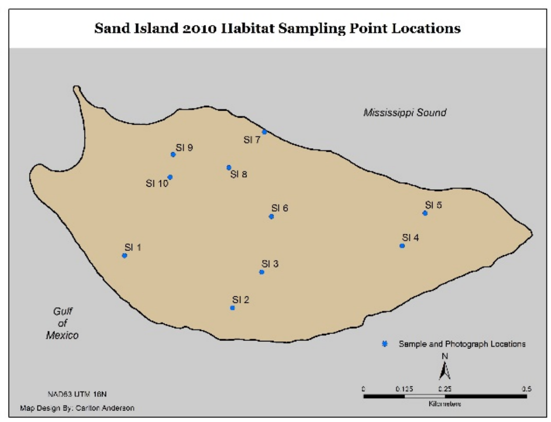


Figure 18. Maps showing all point locations from 2010 that were revisited in 2014. Shorelines from 2010 were used for basemaps to give a representation of the coverage area and random sampling design used in 2010.

Measuring Change

Many repeat photography studies rely solely on qualitative descriptions between photo pairs (Kull, 2005). This study used a hybrid approach of both qualitative and quantitative analysis. Qualitative analysis described each photo pair in detail, distinguishing differences between habitat types, vegetation coverage, and any noticeable geomorphic changes that have occurred as a whole in the fore, middle, and background. This analysis employed broader scale descriptions of changes that took place between individual photo pairs. For the quantitative analysis a tabulation method was used similar to those used in other studies (Bass, 2004; Burton, Mitchell, and Cutter, 2011; Kull, 2005) to identify differences between all individual photo pairs and both islands each as a whole. Photo pairs were tabulated based on a yes-or-no interpretation of whether change occurred throughout several categories, such as habitat type, the pioneering of species in previously unestablished bare sand or algal flats, the increase or decrease in vegetation cover, and any types of geomorphic change. Results for each island were then summed and represented as a percentage of the total number of photographic pairs for each island.

Results

East Ship Island

The qualitative analysis of 44 photographic pairs on East Ship Island produced results that illustrated both landscape continuity and change on the island. Results are reported starting from the northeast spit of the island, transitioning to the west, and terminating in the island's core section, noted by a corresponding point number and cardinal direction of the photographic pair (Appendix E). Sample sites on the northeast spit of the island showed noticeable change to the landscape. The pioneering of flowering and grass species such as *Sesuvium portulacastrum* (sea-purslane) and sea oat were seen in previously uninhabited bare sand and algal flat habitats. Sample points 1, 2, 3, and 4 all showed these changes. Two scenes from point 4 (east and south) did not show any pioneering of these species. Additionally, some slight to moderate beach dune building can be noted between scenes for the most part in sample points 1, 2, 3, and 4. Figure 19 shows changes that were indicative throughout the northeast spit. Lying on the east flank of the central core of the island, sample point 5 showed the most change on the northeast spit from 2010 – 2014. A major increase in vegetation coverage was found throughout all scenes at the location through the pioneering and establishment of *Fimbristylis castanea* (marsh fimbry).

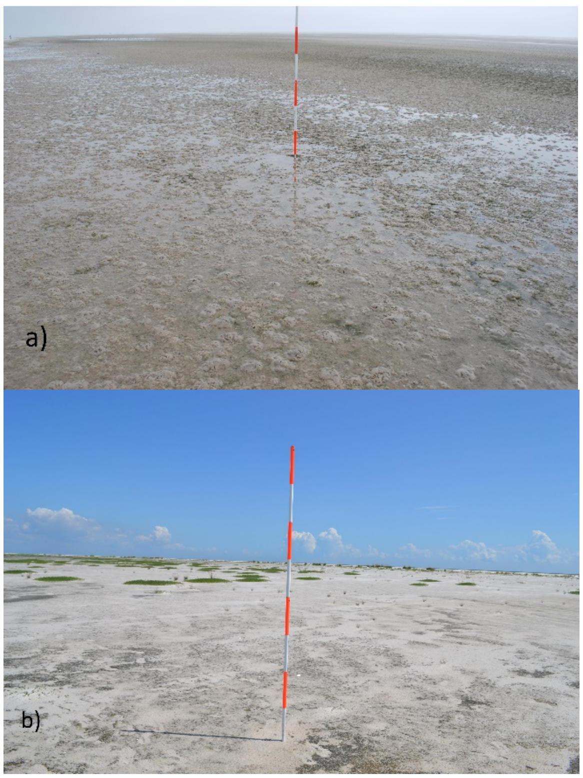


Figure 19. East Ship photo pair 03 east. A vast expanse of algal flat can be seen in the 2010 photo (a). By 2014 (b), much of the same area is starting to colonize with sea-purslane, and elevating with embryo dunes.

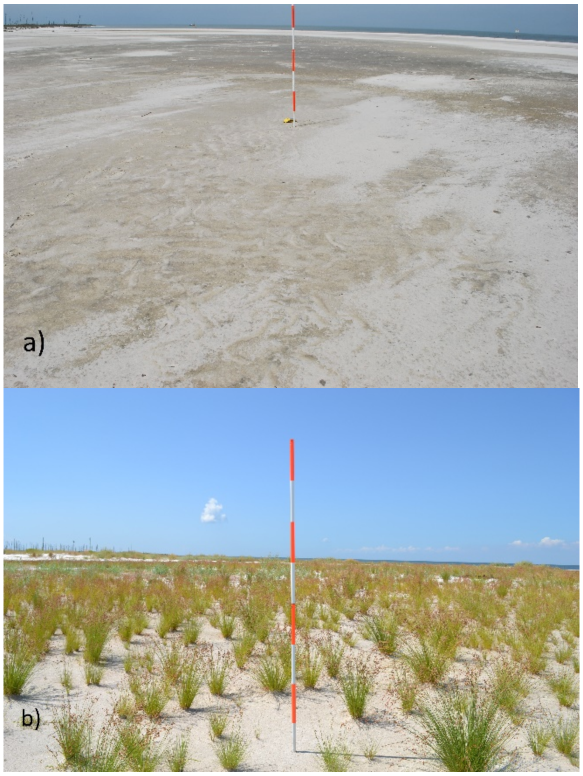


Figure 20. East Ship photo pair 05 west. The algal flat from 2010 (a) has transitioned completely to beach dune herbland by 2014 (b). Pioneering of marsh fimbry can be seen throughout the photo extent helping to establish embryo dunes and elevate the area further.

East Ship Island sample point 6 was the only one located near a shoreline. Only two scenes from the location (north and west) showed some slight foredune building and vegetation increase in the background. The major change to the location was the reduction in projected land area, noticeable in photo pairs 6 east and 6 south (Figure 21). Sample point 7 showed no new pioneering of species; however, there was a moderate increase in sea oat, beach morning glory, and gulf bluestream dune grasses in all photo pairs at the location. Additionally, some slight overwash and dune building can be seen in all scenes. Figure 22 illustrates much of what was telling in all photo pairs for the location between 2010 and 2014. Major changes occurred at sample point 8 with the complete overwashing of most vegetation. Further, dune building and a complete habitat transition from mash shrubland to beach dune herbland took place at the location. Figures 23 and 24 show the overwashing and habitat transitions at sample point 8. Geographically located in the island's central core, sample points 9, 10, and 11 were stable in comparison to other sites on the northeast spit and outer flanks of the island core. These sample points showed no changes in habitat, pioneering of species, dune evolution, or overwash. Photographic pairs at these locations show the continuity and slight coverage growth of the dominant species in the area, such as saltmeadow cordgrass, marsh elder, and sand live oak (Figures 25 and 26).

Figure 21. East Ship photo pair 06 west. Major erosion and the island's geomorphic response type (rotational instability) has led to a noticeable decrease in the island's south shore coverage between 2010 (a) and 2014 (b).

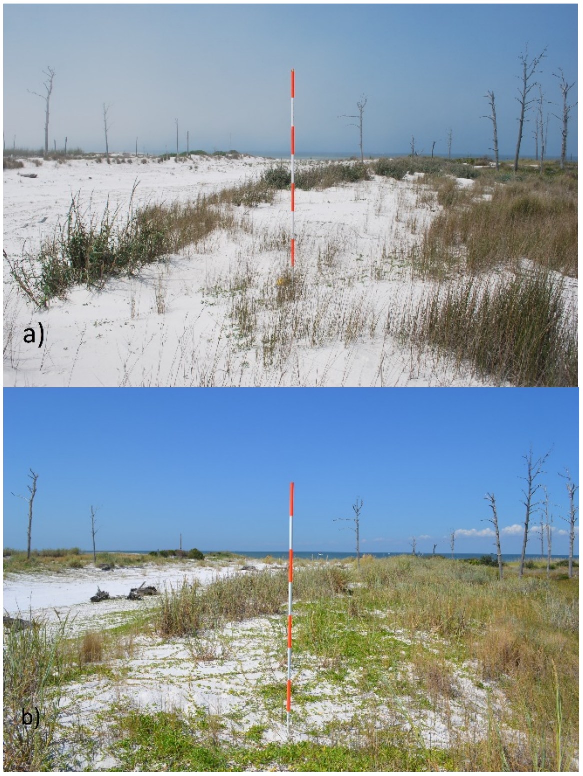


Figure 22. East Ship photo pair 07 west. A moderate increase in the beach dune grasses, such as sea oat, beach morning glory, and gulf bluestream can be seen from 2010 (a) to 2014 (b). Similar trends were found for all photo pairs at this location.

Figure 23. East Ship photo pair 08 east. Marsh shrubland in 2010 (a) transitioned to beach dune herbland by 2014 (b) through the construction of an overwash lobe during Hurricane Isaac in 2012.

Figure 24. East Ship photo pair 08 west. As with the east photo pair at this location, the presence of an overwash lobe has led to a habitat transition from marsh shrubland to beach dune herbland. The marsh elder present in 2010 (a) also appears to have been overwashed and buried in the 2014 (b) photo.

Figure 25. East Ship photo pair 10 north. The stability of the island's central core can be seen between 2010 (a) and 2014 (b) in these photo pairs with marsh elder growth. Additionally, the overall increase of density for the marsh shrubland habitat in the area is apparent.

Figure 26. East Ship photo pair 11 north. Establishing sand live oak in 2010 (a) appears to have increased in density by 2014 (b).

Results from the quantitative analysis were reported as percentage of change from all photographic pairs (Appendix F). A total of 84% of the photographic pairs on East Ship Island showed some kind of ecological or geomorphic change. All four scenes from sample point 9 and two from sample point 4 were the only ones that did not show any identifiable change. Almost half (41%) showed the pioneering of flowering and grass species in bare sand or algal flat, mainly on the northeast spit. Of the 44 photo pairs, 32 (73%) showed an increase in vegetation, 9% showed a decrease, and 20% showed no change. Some dune building was evident in 34% of the photographic pairs on East Ship Island, while none displayed dune erosion. Further, overwashing was apparent in 14% of the repeated scenes. Land loss or gain was noticeable in only 10% of the photo pairs on the island. The minimum elevation for all sample points repeated with the RTK survey on East Ship Island was 0.3 m at location 3 on the northeast spit. The maximum elevation was 2.75 m at point 7 on the fringe of an overwash lobe. The mean elevation of all sample points was 0.9 m with a standard deviation of 0.85 m (Appendix G).

Sand Island

Results are reported starting from the most southwest point, traversing in a counter clockwise fashion, and terminating at the island's central core. As with East Ship Island, photo pairs have a corresponding point number and cardinal direction (Appendix H). Sample point 1 showed no new pioneering of species, with some slight increases to the vegetation, mainly sea oat in the background of photo pairs. Some elevation growth is apparent in the background dunes; however, all scenes at the location show projected area land loss to the island's shoreline. Figure 27 shows changes that were common in all sample point 1 photo pairs. The repeated photographs indicated change at sample point 2. The pioneering of marsh fimbry and gulf bluestream was dominant throughout the location (Figure 28). The habitat changed from bare sand to beach dune herbland with increases to the overall vegetation in the fore, middle, and background of all paired photos. Repeated scene 2 south showed land loss, with the pioneering of species near the shoreline (Figure 29). Changes were also noticeable at sample point 3, with habitat type changing from bare sand to beach dune herbland. Most of the changes in the photo pairs showed the increase of vegetation coverage (Figure 30).

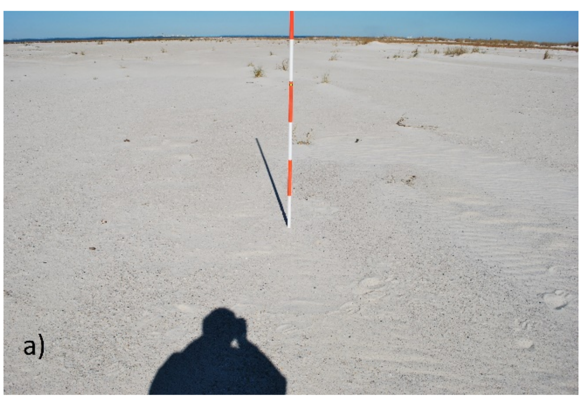


Figure 27. Sand Island photo pair 01 north. Shoreline loss can be noted between the 2010 (a) and 2014 (b) photos. Some foredune growth and slight scarping to foredune is also discernible between the photo pairs.

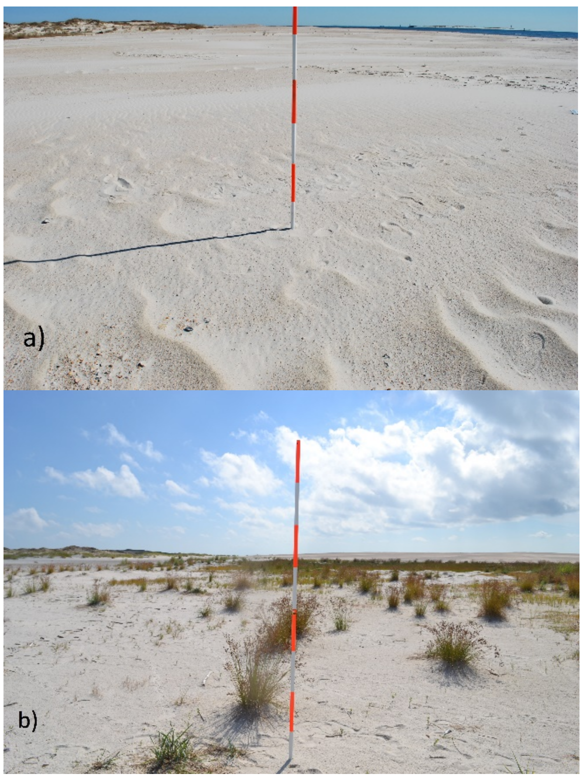


Figure 28. Sand Island photo pair 02 east. A slight reduction in projected land area can be seen in the far background of the photo pairs. However, the pioneering of marsh fimbry and gulf bluestream occurred between 2010 (a) and 2014 (b), promoting embryo dune establishment.

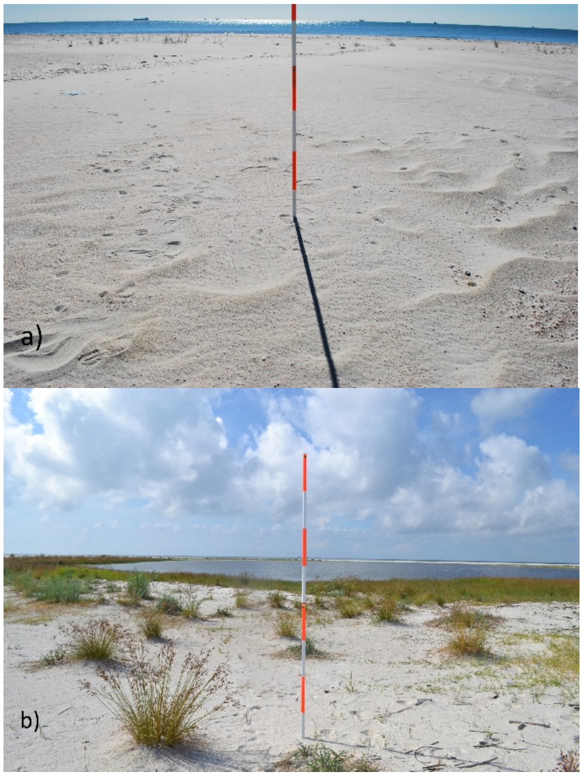
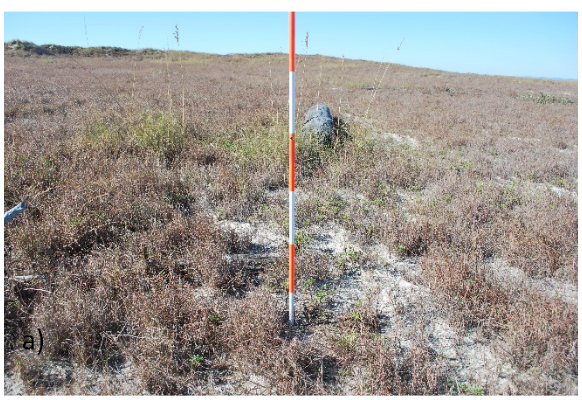


Figure 29. Sand Island photo pair 02 south. A major reduction and reworking of the island’s south shoreline is noticeable between 2010 (a) and 2014 (b). Further, the pioneering of marsh fimbry, gulf bluestream and other marsh grasses took place.

Figure 30. Sand Island photo pair 03 south. Major increases in beach dune vegetation density and coverage between 2010 (a) to 2014 (b).

Sample point 4 was very stable, with no identifiable changes in the vegetation or geomorphic features found throughout the area. Additionally, sample point 5 had only a slight increase to the vegetation density in all its photo pairs. Figure 31 shows the stability of sample point 4 and the surrounding area. Moderate increases in vegetation coverage and density were seen at sample point 6, through the growth and expansion of wax myrtle (Figure 32). The only identifiable changes at sample location 7 were the moderate increase of vegetation in two photo pairs (south and west) and moderate erosion to the dune in the middle ground of photo pair 7 west (Figure 33). Locations 8, 9, and 10 were relatively stable, with changes mainly occurring to the increase of coverage and density of grass species, such as saltmeadow cordgrass and *Paspalum sp.* found in the sites (Figure 34). The presence of saltmeadow loosestrife (*Lythrum lineare*), a species of flowering plant, was identified in all photo pairs from sample point 9 in 2014. Further, the extent of water habitat seen in photo pairs at sample point 10 was stable from 2010 – 2014 (Figure 35).



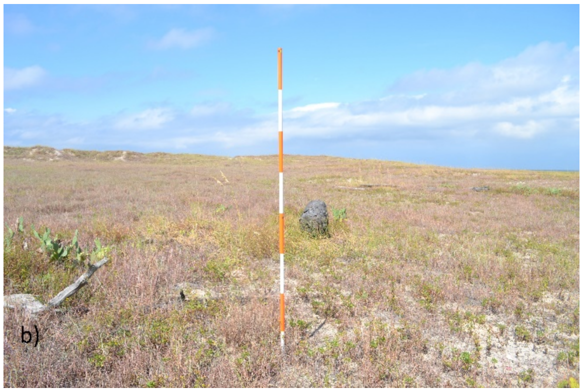


Figure 31. Sand Island photo pair 04 west. The most stable of the sample locations on Sand Island between 2010 (a) and 2014 (b). No changes were identified in any of the photo pairs at this location.

Figure 32. Sand Island photo pair 06 west. A moderate increase to the density and coverage of the climax woody species (wax myrtle) on the island can be seen between 2010 (a) and 2014 (b). The north and east photo pair for this location showed the same growth trend.

Figure 33. Sand Island photo pair 07 west. Moderate dune and shoreline erosion took place between 2010 (a) and 2014 (b), although increases in vegetation density can be seen.

Figure 34. Sand Island photo pair 09 east. Similar vegetation densities can be seen between 2010 (a) and 2014 (b). However, the biggest change was the addition of the saltmeadow loosestrife appearing by 2014 (b), identifiable by the plant's white flowers.

Figure 35. Sand Island photo pair 10 south. The island's freshwater pond remained stable between 2010 (a) and 2014 (b). Further, marsh elder and other grass species appear to have remained at this location.

A total of 26 of the 40 photographic pairs (65%) showed some kind of change on Sand Island from 2010 – 2014. Sample point 4 was the only location in which none of its photo pairs indicate change. Habitat type change was noticeable in 20% of the photo pairs, mainly on the south side of the island. Over half of the photographic pairs (60%) had distinguishable vegetation increases from 2010 – 2014. No changes to vegetation were detected in 35% of the photo pairs, and only 5% showed a decrease in vegetation between the repeated scenes. The analysis revealed dune building (18%) and erosion (5%) occurred less frequently than the number of vegetation changes in the photo pairs examined. Land loss and land gain were seen in only 15% and 5% of the photo pairs respectively (Appendix I). The minimum elevation of all sample points repeated on Sand Island in 2014 was 0.31 m at sample point location 10, located in the central core of the island. The maximum elevation for these locations was 3.81 m at sample point 5. The sample points had a mean elevation of 1.16 m, with a standard deviation of 1.03 m (Appendix J).

Discussion

By using a hybrid method of qualitative descriptions coupled with a quantitative analysis, this study has allowed for a better understanding of short-term change on East Ship Island and Sand Island. Both islands have undergone noticeable change since the 2010 survey. As mentioned in Chapter III of this thesis, Hurricane Isaac passed to the west of these two islands in late-summer 2012, roughly two years pre and post initial survey of these sites. Many of the apparent changes between the photo pairs can be attributed to the effects the storm had on these islands. The central cores of the islands stayed intact and stable through Isaac, even supporting growth of vegetation at some locations. Most of the major changes took place out from the central cores on their flanks and extended out to the shorelines.

The northeast spit of East Ship Island underwent the biggest changes from Hurricane Isaac. Maun (2009) describes embryo dunes as the initial phase of new dune growth due to pioneering species. Dotted all over this landscape are the initial pioneering of many flowering and grass species and their colonization of small embryo dunes. In some cases, a complete habitat transition from algal flat to beach dune herbland has occurred. The elevation of the spit also appears higher, suggesting run-up overwash from Isaac caused sediment deposition on the spit, elevating it and promoting new vegetation growth. This phenomenon is prominent at sample point 5 on the east flank of island's core, where a vast expanse of marsh fimbry has begun to vegetate the area, stimulating sediment accretion and the ultimate building of dunes. The storm took a toll on the island's south shoreline, where major erosion is apparent in two of the photo pairs. East Ship Island is experiencing rotational instability, causing overall reduction of the south shore (McBride, Byrnes, and Hiland, 1994). These conditions were exacerbated during Isaac. Much of the erosion on the south shore of the island appears to have been deposited on foredunes, evident in slight elevation increases of the dunes in the background of two photo pairs. Additionally, to the west of East Ship's core many locations showed evidence of overwashing, sand burial, and the reestablishment of beach grass species such as sea oat and beach morning glory. A major overwash channel was noted near sample points 7 and 8 which served as a conduit for sediment entrainment and deposition during Isaac. One location (sample point 8) shows overwash lobes caused habitat transitions from marsh shrubland to beach dune herbland. Further, marsh elder in the background of the repeated north scene at point 8 is no longer there. The core of East Ship Island stayed stable through Hurricane Isaac from foredune protection, as its elevation (0.36 m at sample point 10) is clearly below recorded storm tide levels. Overall, the island appears to have benefitted from Isaac's run-up overwash, as most sediment deposition took place directly on the island or in areas favorable for littoral drift.

Increases in elevation were not as noticeable on Sand Island as they were on East Ship. The only evidence for elevation increase exists in some foredune growth in the background of photo pairs for sample points 1 and 2. Shoreline loss, however, is apparent in more of the photo pairs for Sand Island than for East Ship. The southwest shore of the island appears to have been overwashed with minimal sediment deposition on the island with the majority lost to the Mississippi Sound. Further, some scarping of foredunes can be seen from the reduction in projected land area on the island's south shore from Isaac. However, the dominant changes to Sand Island were mainly caused by the increase of vegetation coverage and density. The RTK survey showed Sand Island's sample points had a mean elevation higher than those for East Ship Island, suggesting the island's higher mean elevation helped it to maintain habitat stability through Hurricane Isaac. Further, the presence of the saltmeadow loosestrife in 2014 on Sand Island is a mystery, as it has not been documented in the literature on any of the other islands in the MS-AL barrier island chain. The addition of this flowering plant suggests new species propagation is occurring on the island.

CHAPTER V

CONCLUSIONS

East Ship and Sand Island represent a small piece of the MS-AL barrier island chain, nevertheless this investigation has provided valuable insight into the short-term dynamics of their vegetated habitats and landforms. With the exception of the algal flat habitat on East Ship Island, both islands have similar habitat types and coverage. Other than one casually observed juvenile slash pine and a small patch of establishing sand live oak on East Ship, as well as the saltmeadow loosestrife on Sand Island, both islands have very similar species of vegetation comprising their habitats. The lack of slash pine and sand live oak on Sand Island is more than likely due to the dominant southeast wind direction on the chain throughout most of the year. Sand Island may be in an unfavorable location for seed dispersal, as neighboring Horn Island to the west has established stands of healthy slash pine. Therefore, wax myrtle and marsh elder are currently the climax community species on both islands. Marsh shrubland, consisting of wax myrtle and marsh elder, is more abundant on East Ship than on Sand Island in relation to percentage of total island coverage. Both islands have the same primary species of vegetation in the beach dune herbland class. However, Sand Island's coverage is greater in comparison to East Ship, with the habitat representing roughly three times more of the island's total land area. Further, beach dune herbland on Sand Island appears to be denser than that found on East Ship Island. This phenomenon may be due to the abundance of organic matter introduced to the islands surface through additional artificial sediment deposition in dredging operations. Bare sand on both islands represented at least half of the total land area for all years studied.

With a maximum elevation of 9.34 m, Sand Island is considerably higher than East Ship Island at its highest point of 4.50 m. Sand Island's higher elevation is more than likely due to the combined amount of artificial deposition taken place on the island since its inception and its location in the chain in relation to littoral drift cells. This has led to higher mean elevations for all habitats on Sand Island in comparison to East Ship. Further, the ranges of elevation within a given habitat is also higher on Sand Island. Mean elevations for stable habitats, such as water and marshland, were similar on both islands, but the more dynamic habitats, bare sand and beach dune herbland, were higher on Sand Island. A commonality does exist between East Ship and Sand Island, in that both have habitat transitions occurring about every 0.3 m of elevation increase or decrease. Although East Ship added ~2 km of spit growth northeast and southeast of its core between 2007 and 2012 and has a larger projected land area than Sand Island, as of 2012 its total volume was somewhat less than Sand by ~341,357.8 m^3.

Both of these islands have experienced considerable amounts of change from 2007 – 2012. Most of the changes were attributed to the passing of two hurricanes to the west of the study area. While these events were weak in comparison to previous major storms affecting the MS-AL chain, such as Katrina and Camille, they did produce a formidable amount of wind, wave, and surge energies. Moderate-sized tropical events affect the chain more often than Katrina-sized storms. Hurricanes Gustav and Isaac created overwash situations on both islands, reducing overall habitat coverage, especially beach dune herbland. After Hurricane Gustav, the habitat was reduced by roughly half on Sand and 90% on East Ship. However, rebounding growth was rapid, with the reestablishment of the habitat occurring within two years. Based on repeat photography, the trend appears to be similar post-Isaac, with reestablishment of beach dune herbland in areas that were lost to the storm. Gustav and Isaac had different effects on these two islands, but in the case of East Ship, both storms aided in the expansion of the island's total projected land area. Intertidal berm-basins that emerged on shoal platforms eroded previously by Katrina, began to establish themselves pre-Gustav (Otvos and Carter, 2013). Through berm-basin building and sediment deposition in Gustav, a large algal flat formed on East Ship's northeast spit. The flat was subsequently overwashed and elevated in Isaac, helping to promote seed germination and the establishment of embryo dunes in the area. Further, about 0.75 km of spit growth from Isaac's overwash and sediment deposition on the southeast spit. Samples points from the RTK survey on the northeast spit that were below sea-level in 2007, were ~0.6 m above sea-level in 2014. Further, areas of algal flat in 2010 were completely colonized in 2014 with dune grasses through elevation added by Isaac. Clearly Isaac helped in promoting land area growth and elevation on East Ship. Although Isaac caused a projected land area reduction on Sand Island, it did elevate some of the island's foredunes, promoting new growth of pioneering species.

As tropical events are the main reason for the most drastic and sudden changes on barrier island systems, they can be either beneficial or detrimental. Tropical impacts along the NGOM are part of the MS-AL barrier island chain's natural life cycle, promoting new growth and development out of destruction. These two islands are very dynamic undergoing primary succession with new land gain and secondary succession with the reestablishment of habitats in short periods of time. Above all, Hurricanes Gustav and Isaac were ultimately beneficial for both of these islands, stimulating both total land area and habitat growth. West and East Ship Island's spit growth during storm-free periods almost closed Camille Cut (Otvos and Carter, 2008). Through present rates of spit extension and addition on East Ship Island, pre- Georges and Katrina island length may be achievable naturally.

Technically man-made, Sand Island has many characteristics of a "natural" barrier island. Otvos and Carter (2008) noted the presence of elongated east-west recurved truncated beach dune ridges on the island. Additionally, foredunes are classified as dune features behind and along the high tide line shore-parallel landward of the islands beach shore (Otvos, 2011). These features are clearly identifiable in NAIP imagery, ML classifications, DTMs, and repeat photographic pairs of the island. Further, habitats are very similar to those found on the "natural" East Ship Island. The presence of beach dune herbland, marsh shrubland and freshwater pond habitats on Sand Island suggest a freshwater lens on Sand Island, indicating overall barrier island stability. Moreover, through repeat photography it was noted the climax woody species on the island is currently expanding, promoting further growth and stability. The borrowing of sediment from Sand Island for restoration projects on the MS-AL chain will ultimately effect species seed propagation and pioneering, habitat succession, and dune elevation controls, leading to a decline in the overall stability of the island. Sediment loss downdrift of Petit Bois will be exacerbated without Sand Island helping to control sediment transport. The succession of habitat on both natural and man-made islands in the NGOM are fairly rapid. While there was no prescribed amount of time found for the genesis of a dredge spoil to evolve into a barrier island, it is evident that once initial pioneering of vegetation starts, succession occurs quickly thereafter. However, elevation and near-shore bathymetry are key factors in their habitat development and evolution. Sand Island's short-term evolution into a barrier island was a direct result of this notion, as is evident throughout this study. Although Sand Island is man-made and nearly 4.5 ka younger than East Ship Island, it shows very similar successional traits, both geomorphically and ecologically, developing from a dredge spoil into a stable barrier island complete with both flora and fauna habitats.

This study was conducted out of the growing need for exploratory research concerning short-term habitat and geomorphic change on the MS-AL barrier island chain. Hurricane Katrina caused massive amounts of erosion and land loss to the chain, sparking awareness for the need to restore these islands to pre-storm projected land areas, especially the Ship Islands (USACE, 2014). However, short temporal scale studies of habitat make-up and the changes they undergo are deficient in the literature. This research will aid in the understanding of potential effects island restoration may have on natural and man-made ecosystems, short and long-term. East Ship and Sand Island were chosen for this study due to their different formation histories and similar projected land areas in 2007. Data for this project have been backed up on internal servers with the GCGC and will serve as a baseline for ongoing projects concerning relative sea-level rise, spatial modeling, and prediction of habitat change, and short and long-term comparison studies on barrier islands throughout the NGOM.

APPENDIX A

HABITAT SURFACE PERCENT REFLECTANCE VALUES FOR EAST SHIP AND SAND ISLAND AND CONFUSION MAXTRIX REPORTS FOR EAST SHIP ISLAND ML CLASSIFICATIONS

Habitat Surface Reflectance Threshold Values

	AF	BS	BDH	MS	W
East Ship Island	37.5 – 41.0	> 52.6	41.1 – 52.5	35.5 – 37.5	30.0 – 35.4
Sand Island	Null	> 50.0	41.0 – 46.0	31.0 – 35.5	35.6 – 40.0

Confusion Matrix: East Ship Island Core 2007

Overall Accuracy = (6812/6813) 99.9853%
Kappa Coefficient = 0.9998

	Ground Truth (Pixels)				
Class	BS	BDH	MS	W	Total
Unclassified	0	0	0	0	0
BS	3192	0	0	0	3192
BDH	0	310	0	0	310
MS	0	0	582	1	583
W	0	0	0	2728	2728
Total	3192	310	582	2729	6813

Ground Truth (Percent)

Class	BS	BDH	MS	W	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
BS	100.00	0.00	0.00	0.00	46.85
BDH	0.00	100.00	0.00	0.00	4.55
MS	0.00	0.00	100.00	0.04	8.56
W	0.00	0.00	0.00	99.96	40.04
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.00	0.00	0/3192	0/3192
BDH	0.00	0.00	0/310	0/310
MS	0.17	0.00	1/583	0/582
W	0.00	0.04	0/2728	1/2729

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	100.00	100.00	3192/3192	3192/3192
BDH	100.00	100.00	310/310	310/310
MS	100.00	99.83	582/582	582/583
W	99.96	100.00	2728/2729	2728/2728

Confusion Matrix: East Ship Island East End 2007

Overall Accuracy = (3773/3826) 98.6147%
Kappa Coefficient = 0.9593

Ground Truth (Pixels)

Class	BS	AF	Total
Unclassified	0	0	0
BS	2967	0	2967
AF	53	806	859
Total	3020	806	3826

Ground Truth (Percent)

Class	BS	AF	Total
Unclassified	0.00	0.00	0.00
BS	98.25	0.00	77.55
AF	1.75	100.00	22.45
Total	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.00	1.75	0/2967	53/3020
AF	6.17	0.00	53/859	0/806

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	98.25	100.00	2967/3020	2967/2967
AF	100.00	93.83	806/806	806/859

Confusion Matrix: East Ship Island Core 2009

Overall Accuracy = (3538/3707) 95.4411%
Kappa Coefficient = 0.9077

Ground Truth (Pixels)

Class	BS	BDH	MS	W	Total
Unclassified	0	0	0	0	0
BS	2387	150	0	0	2537
BDH	0	38	19	0	57
MS	0	0	194	0	194
W	0	0	0	2728	2728
Total	2387	188	213	919	3707

Ground Truth (Percent)

Class	BS	BDH	MS	W	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
BS	100.00	79.79	0.00	0.00	68.44
BDH	0.00	20.21	8.92	0.00	1.54
MS	0.00	0.00	91.08	0.00	5.23
W	0.00	0.00	0.00	100.00	24.79
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	5.91	0.00	150/2537	0/2387
BDH	33.33	79.79	19/57	150/188
MS	0.00	8.92	0/194	19/213
W	0.00	0.00	0/919	0/919

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	100.00	94.09	2387/2387	2387/2537
BDH	20.21	66.67	38/188	38/57
MS	91.08	100.00	194/213	194/194
W	100.00	100.00	919/919	919/919

Confusion Matrix: East Ship Island East End 2009

Overall Accuracy = (28599/28653) 99.8115%
Kappa Coefficient = 0.9941

Ground Truth (Pixels)

Class	BS	AF	Total
Unclassified	0	0	0
BS	22959	0	22959
AF	54	5640	5694
Total	23013	5640	28653

Ground Truth (Percent)

Class	BS	AF	Total
Unclassified	0.00	0.00	0.00
BS	99.77	0.00	80.13
AF	0.23	100.00	19.87
Total	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.00	0.23	0/22959	54/23013
AF	0.95	0.00	54/5694	0/5640

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	99.77	100.00	22959/23013	22959/22959
AF	100.00	99.05	5640/5640	5640/5694

Confusion Matrix: East Ship Island Core 2010

Overall Accuracy = (1846/1848) 99.8918%
Kappa Coefficient = 0.9983

Ground Truth (Pixels)

Class	BS	BDH	MS	W	Total
Unclassified	0	0	0	0	0
BS	260	0	0	0	260
BDH	0	229	0	0	229
MS	0	0	346	2	348
W	0	0	0	1011	1011
Total	260	229	346	1013	1848

Ground Truth (Percent)

Class	BS	BDH	MS	W	Total
Unclassified	0.00	0.00	0.00	0.00	0.00

BS	100.00	0.00	0.00	0.00	14.07
BDH	0.00	100.0	0.00	0.00	12.39
MS	0.00	0.00	100.0	0.20	15.83
W	0.00	0.00	0.00	99.80	54.71
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.00	0.00	0/260	0/260
BDH	0.00	0.00	0/229	0/229
MS	0.57	0.00	2/348	0/346
W	0.00	0.20	0/1011	2/1013

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	100.00	100.00	260/260	260/260
BDH	100.00	100.00	229/229	229/229
MS	100.00	99.43	346/346	347/348
W	99.80	100.00	1013/1012	1011/1011

Confusion Matrix: East Ship Island East End 2010

Overall Accuracy = (4231/5132) 82.4435%
Kappa Coefficient = 0.6310

Class	Ground Truth (Pixels) BS	AF	Total
Unclassified	0	0	0
BS	1512	237	1749
AF	664	2719	3383
Total	2176	2956	5132

Class	Ground Truth (Percent) BS	AF	Total
Unclassified	0.00	0.00	0.00
BS	69.49	8.02	34.08
AF	30.51	91.98	65.92
Total	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	13.55	30.51	237/1749	664/2176
AF	19.63	8.02	664/3383	237/2956

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	69.49	86.45	1512/2176	1512/1749
AF	91.98	80.37	2719/2956	2719/3383

Confusion Matrix: East Ship Island Core 2012

Overall Accuracy = (4446/4666) 95.2850%
Kappa Coefficient = 0.9332

Class	Ground Truth (Pixels) BS	BDH	MS	W	Total
Unclassified	0	0	0	0	0
BS	1711	7	0	0	1718
BDH	16	431	0	0	447
MS	0	6	894	161	1061
W	0	0	30	1410	1440
Total	1727	444	924	1571	4666

Class	Ground Truth (Percent) BS	BDH	MS	W	Total
Unclassified	0.00	0.00	0.00	0.00	0.00

BS	99.07	1.58	0.00	0.00	36.82
BDH	0.93	97.07	0.00	0.00	9.58
MS	0.00	1.35	96.75	10.25	22.74
W	0.00	0.00	3.25	89.75	30.86
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.41	0.93	7/1718	16/1727
BDH	3.58	2.93	16/447	13/444
MS	15.74	3.25	167/1061	30/924
W	2.08	10.25	30/1440	161/1571

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	99.07	99.59	1711/1727	1711/1718
BDH	97.07	96.42	431/444	431/447
MS	96.75	84.26	894/924	894/1061
W	89.75	97.92	1410/1571	1410/1440

Confusion Matrix: East Ship Island East End 2012

Overall Accuracy = (21384/21398) 99.9346%
Kappa Coefficient = 0.9794

Ground Truth (Pixels)			
Class	BS	AF	Total
Unclassified	0	0	0
BS	7	21046	21052
AF	338	7	7
Total	345	21053	21398

Ground Truth (Percent)			
Class	BS	AF	Total
Unclassified	0.00	0.00	0.00
BS	2.03	99.97	98.39
AF	97.97	0.03	1.61
Total	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.03	0.03	7/21053	7/21053
AF	2.03	2.03	7/345	7/345

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	99.97	99.97	21046/21053	21046/21053
AF	97.97	97.97	338/345	338/345

APPENDIX B

EAST SHIP ISLAND CHANGE DETECTION RESULTS

East Ship Island Change Detection 2007-2009

Pixel Counts

	Algal flat 2007	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	1	104029	1663	904	535	13467213	13574345	13574345
Algal flat 2009	7255	11416	81	1	0	189037	207790	207790
Bare sand 2009	15807	196502	92318	30444	3597	92440	431108	431108
Beach dune herbland 2009	0	2181	6803	8650	1381	763	19778	19778
Marsh shrubland 2009	0	864	5546	56613	2737	291	66051	66051
Water 2009	0	0	4	2967	14352	0	17323	17323
Class Total	23063	314992	106415	99579	22602	13749744	0	0
Class Changes	15808	118490	99612	42966	8250	282531	0	0
Image Difference	184727	116116	-86637	-33528	-5279	-175399	0	0

Percentages

	Algal flat 2007	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	0.004	33.026	1.563	0.908	2.367	97.945	100	100
Algal flat 2009	31.457	3.624	0.076	0.001	0	1.375	100	100
Bare sand 2009	68.538	62.383	86.753	30.573	15.915	0.672	100	100
Beach dune herbland 2009	0	0.692	6.393	8.687	6.11	0.006	100	100
Marsh shrubland 2009	0	0.274	5.212	56.852	12.11	0.002	100	100
Water 2009	0	0	0.004	2.98	63.499	0	100	100
Class Total	100	100	100	100	100	100	0	0
Class Changes	68.543	37.617	93.607	43.148	36.501	2.055	0	0
Image Difference	800.967	36.863	-81.414	-33.67	-23.356	-1.276	0	0

Area (Hectares)

	Algal flat 2007	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	0.0001	10.4029	0.1663	0.0904	0.0535	1346.7213	1357.435	1357.4345
Algal flat 2009	0.7255	1.1416	0.0081	0.0001	0	18.9037	20.779	20.779
Bare sand 2009	1.5807	19.6502	9.2318	3.0444	0.3597	9.244	43.1108	43.1108
Beach dune herbland 2009	0	0.2181	0.6803	0.865	0.1381	0.0763	1.9778	1.9778
Marsh shrubland 2009	0	0.0864	0.5546	5.6613	0.2737	0.0291	6.6051	6.6051
Water 2009	0	0	0.0004	0.2967	1.4352	0	1.7323	1.7323
Class Total	2.3063	31.4992	10.6415	9.9579	2.2602	1374.9744	0	0
Class Changes	1.5808	11.849	9.9612	4.2966	0.825	28.2531	0	0
Image Difference	18.4727	11.6116	-8.6637	-3.3528	-0.5279	-17.5399	0	0

East Ship Island Change Detection 2009-2010

Pixel Counts

	Algal flat 2009	Bare sand 2009	Beach dune herbland 2009	Marsh shrubland 2009	Water 2009	Unclassified	Row Total	Class Total
Unclassified	6865	57662	1174	658	0	13538073	13604432	13604432
Algal flat 2010	115199	3770	0	0	0	612	119581	119581
Bare sand 2010	85726	321311	2639	1552	306	35212	446746	446746
Beach dune herbland 2010	0	42904	7268	4584	249	448	55453	55453
Marsh shrubland 2010	0	5449	8649	57028	3211	0	74337	74337
Water 2010	0	12	48	2229	13557	0	15846	15846
Class Total	207790	431108	19778	66051	17323	13574345	0	0
Class Changes	92591	109797	12510	9023	3766	36272	0	0
Image Difference	-88209	15638	35675	8286	-1477	30087	0	0

Percentages

	Algal flat 2009	Bare sand 2009	Beach dune herbland 2009	Marsh shrubland 2009	Water 2009	Unclassified	Row Total	Class Total
Unclassified	3.304	13.375	5.936	0.996	0	99.733	100	100
Algal flat 2010	55.44	0.874	0	0	0	0.005	100	100
Bare sand 2010	41.256	74.531	13.343	2.35	1.766	0.259	100	100
Beach dune herbland 2010	0	9.952	36.748	6.94	1.437	0.003	100	100
Marsh shrubland 2010	0	1.264	43.73	86.339	18.536	0	100	100
Water 2010	0	0.003	0.243	3.375	78.26	0	100	100
Class Total	100	100	100	100	100	100	0	0
Class Changes	44.56	25.469	63.252	13.661	21.74	0.267	0	0
Image Difference	-42.451	3.627	180.377	12.545	-8.526	0.222	0	0

Area (Hectares)

	Algal flat 2009	Bare sand 2009	Beach dune herbland 2009	Marsh shrubland 2009	Water 2009	Unclassified	Row Total	Class Total
Unclassified	0.6865	5.7662	0.1174	0.0658	0	1353.8073	1360.443	1360.4432
Algal flat 2010	11.5199	0.377	0	0	0	0.0612	11.9581	11.9581
Bare sand 2010	8.5726	32.1311	0.2639	0.1552	0.0306	3.5212	44.6746	44.6746
Beach dune herbland 2010	0	4.2904	0.7268	0.4584	0.0249	0.0448	5.5453	5.5453
Marsh shrubland 2010	0	0.5449	0.8649	5.7028	0.3211	0	7.4337	7.4337
Water 2010	0	0.0012	0.0048	0.2229	1.3557	0	1.5846	1.5846
Class Total	20.779	43.1108	1.9778	6.6051	1.7323	1357.4345	0	0
Class Changes	9.2591	10.9797	1.251	0.9023	0.3766	3.6272	0	0
Image Difference	-8.8209	1.5638	3.5675	0.8286	-0.1477	3.0087	0	0

East Ship Island Change Detection 2010-2012

Pixel Counts

	Algal flat 2010	Bare sand 2010	Beach dune herbland 2010	Marsh shrubland 2010	Water 2010	Unclassified	Row Total	Class Total
Unclassified	0	64811	1969	130	0	13288694	13355604	13355604
Algal flat 2012	1925	4378	2	0	0	23543	29848	29848
Bare sand 2012	117656	359228	34325	8260	597	291399	811465	811465
Beach dune herbland 2012	0	14173	8507	3280	118	537	26615	26615
Marsh shrubland 2012	0	4156	10641	61171	6730	259	82957	82957
Water 2012	0	0	9	1496	8401	0	9906	9906
Class Total	119581	446746	55453	74337	15846	13604432	0	0
Class Changes	117656	87518	46946	13166	7445	315738	0	0
Image Difference	-89733	364719	-28838	8620	-5940	-248828	0	0

Percentages

	Algal flat 2010	Bare sand 2010	Beach dune herbland 2010	Marsh shrubland 2010	Water 2010	Unclassified	Row Total	Class Total
Unclassified	0	14.507	3.551	0.175	0	97.679	100	100
Algal flat 2012	1.61	0.98	0.004	0	0	0.173	100	100
Bare sand 2012	98.39	80.41	61.899	11.112	3.768	2.142	100	100
Beach dune herbland 2012	0	3.172	15.341	4.412	0.745	0.004	100	100
Marsh shrubland 2012	0	0.93	19.189	82.289	42.471	0.002	100	100
Water 2012	0	0	0.016	2.012	53.017	0	100	100
Class Total	100	100	100	100	100	100	0	0
Class Changes	98.39	19.59	84.659	17.711	46.983	2.321	0	0
Image Difference	-75.04	81.639	-52.004	11.596	-37.486	-1.829	0	0

Area (Hectares)

	Algal flat 2010	Bare sand 2010	Beach dune herbland 2010	Marsh shrubland 2010	Water 2010	Unclassified	Row Total	Class Total
Unclassified	0	6.4811	0.1969	0.013	0	1328.8694	1335.56	1335.5604
Algal flat 2012	0.1925	0.4378	0.0002	0	0	2.3543	2.9848	2.9848
Bare sand 2012	11.7656	35.9228	3.4325	0.826	0.0597	29.1399	81.1465	81.1465
Beach dune herbland 2012	0	1.4173	0.8507	0.328	0.0118	0.0537	2.6615	2.6615
Marsh shrubland 2012	0	0.4156	1.0641	6.1171	0.673	0.0259	8.2957	8.2957
Water 2012	0	0	0.0009	0.1496	0.8401	0	0.9906	0.9906
Class Total	11.9581	44.6746	5.5453	7.4337	1.5846	1360.4432	0	0
Class Changes	11.7656	8.7518	4.6946	1.3166	0.7445	31.5738	0	0
Image Difference	-8.9733	36.4719	-2.8838	0.862	-0.594	-24.8828	0	0

East Ship Island Change Detection 2007-2012

Pixel Counts

	Algal flat 2007	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	51	158119	7107	2944	1825	13185558	13355604	13355604
Algal flat 2012	389	1105	9	0	0	28345	29848	29848
Bare sand 2012	22602	144585	78726	24971	5661	534920	811465	811465
Beach dune herbland 2012	21	7878	10194	6913	919	690	26615	26615
Marsh shrubland 2012	0	3305	10310	63155	5956	231	82957	82957
Water 2012	0	0	69	1596	8241	0	9906	9906
Class Total	23063	314992	106415	99579	22602	13749744	0	0
Class Changes	22674	170407	96221	36424	14361	564186	0	0
Image Difference	6785	496473	-79800	-16622	-12696	-394140	0	0

Percentages

	Algal flat 2007	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	0.221	50.198	6.679	2.956	8.075	95.897	100	100
Algal flat 2012	1.687	0.351	0.008	0	0	0.206	100	100
Bare sand 2012	98.001	45.901	73.98	25.077	25.046	3.89	100	100
Beach dune herbland 2012	0.091	2.501	9.579	6.942	4.066	0.005	100	100
Marsh shrubland 2012	0	1.049	9.688	63.422	26.352	0.002	100	100
Water 2012	0	0	0.065	1.603	36.461	0	100	100
Class Total	100	100	100	100	100	100	0	0
Class Changes	98.313	54.099	90.421	36.578	63.539	4.103	0	0
Image Difference	29.419	157.614	-74.989	-16.692	-56.172	-2.867	0	0

Area (Hectares)

	Algal flat 2007	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	0.0051	15.8119	0.7107	0.2944	0.1825	1318.5558	1335.56	1335.5604
Algal flat 2012	0.0389	0.1105	0.0009	0	0	2.8345	2.9848	2.9848
Bare sand 2012	2.2602	14.4585	7.8726	2.4971	0.5661	53.492	81.1465	81.1465
Beach dune herbland 2012	0.0021	0.7878	1.0194	0.6913	0.0919	0.069	2.6615	2.6615
Marsh shrubland 2012	0	0.3305	1.031	6.3155	0.5956	0.0231	8.2957	8.2957
Water 2012	0	0	0.0069	0.1596	0.8241	0	0.9906	0.9906
Class Total	2.3063	31.4992	10.6415	9.9579	2.2602	1374.9744	0	0
Class Changes	2.2674	17.0407	9.6221	3.6424	1.4361	56.4186	0	0
Image Difference	0.6785	49.6473	-7.98	-1.6622	-1.2696	-39.414	0	0

APPENDIX C

CONFUSION MAXTRIX REPORTS FOR SAND ISLAND ML CLASSIFICATIONS

Confusion Matrix: Sand Island 2007

Overall Accuracy = (2983/2999) 99.4665%
Kappa Coefficient = 0.9917

Ground Truth (Pixels)					
Class	BS	BDH	MS	W	Total
Unclassified	0	0	0	0	0
BS	1463	0	0	0	1463
BDH	14	904	0	0	918
MS	0	2	302	0	304
W	0	0	0	314	314
Total	1477	906	302	314	2999

Ground Truth (Percent)					
Class	BS	BDH	MS	W	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
BS	99.05	0.00	0.00	0.00	48.78
BDH	0.95	99.78	0.00	0.00	30.61
MS	0.00	0.22	100.00	0.00	10.14
W	0.00	0.00	0.00	100.00	10.47
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.00	0.95	0/1463	14/1477
BDH	1.53	0.22	14/918	2/906
MS	0.66	0.00	2/304	0/302
W	0.00	0.00	0/314	0/314

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	99.05	100.00	1463/1477	1463/1463
BDH	99.78	98.47	904/906	904/918
MS	100.00	99.34	302/302	302/304
W	100.00	100.00	314/314	314/314

Confusion Matrix: Sand Island 2009

Overall Accuracy = (2107/2138) 98.5500%
Kappa Coefficient = 0.9682

Ground Truth (Pixels)				
Class	BS	BDH	MS	Total
Unclassified	0	0	0	0
BS	1514	1	0	1515
BDH	0	314	30	344
MS	0	0	279	279
Total	1514	315	309	2138

Ground Truth (Percent)				
Class	BS	BDH	MS	Total
Unclassified	0.00	0.00	0.00	0.00
BS	100.00	0.32	0.00	70.86
BDH	0.00	99.68	9.71	16.09
MS	0.00	0.00	90.29	13.05
Total	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.07	0.00	1/1515	0/1514
BDH	8.72	0.32	30/344	1/315
MS	0.00	9.71	0/279	30/309

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	100.00	99.93	1514/1514	1514/1515
BDH	99.68	91.28	314/315	314/344
MS	90.29	100.00	279/309	279/279

Confusion Matrix: Sand Island 2010

Overall Accuracy = (899/927) 96.9795%
Kappa Coefficient = 0.9574

Ground Truth (Pixels)

Class	BS	BDH	MS	W	Total
Unclassified	0	0	0	0	0
BS	360	1	0	0	361
BDH	0	137	0	0	137
MS	0	0	271	27	298
W	0	0	0	131	131
Total	360	138	271	158	927

Ground Truth (Percent)

Class	BS	BDH	MS	W	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
BS	100.00	0.72	0.00	0.00	38.94
BDH	0.00	99.28	0.00	0.00	14.78
MS	0.00	0.00	100.00	17.09	32.15
W	0.00	0.00	0.00	82.91	14.13
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.28	0.00	1/361	0/360
BDH	0.00	0.72	0/137	1/138
MS	9.06	0.00	27/298	0/271
W	0.00	17.09	0/131	27/158

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	100.00	99.72	360/360	360/361
BDH	99.28	100.00	137/138	137/137
MS	100.00	90.94	271/271	271/298
W	82.91	100.00	131/158	131/131

Confusion Matrix: Sand Island 2012

Overall Accuracy = (845/858) 98.4848%
Kappa Coefficient = 0.9783

Ground Truth (Pixels)

Class	BS	BDH	MS	W	Total
Unclassified	0	0	0	0	0
BS	339	0	0	0	339
BDH	12	144		0	0
MS	0	90	96	1	97
W	0	0	0	266	266
Total	351	96	267	144	858

Ground Truth (Percent)

Class	BS	BDH	MS	W	Total
Unclassified	0.00	0.00	0.00	0.00	0.00
BS	96.58	0.00	0.00	0.00	39.51
BDH	3.42	100.00	0.00	0.00	18.18
MS	0.00	0.00	100.00	0.37	11.31
W	0.00	0.00	0.00	99.63	31.00
Total	100.00	100.00	100.00	100.00	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
BS	0.00	3.42	0/339	12/351
BDH	7.69	0.00	12/156	0/144
MS	1.03	0.00	1/97	0/96
W	0.00	0.37	0/266	1/267

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
BS	96.58	100.00	339/351	339/339
BDH	100.00	92.31	144/144	144/156
MS	100.00	98.97	96/96	96/97
W	99.63	100.00	266/267	266/266

APPENDIX D

SAND ISLAND CHANGE DETECTION RESULTS

Sand Island Change Detection 2007-2009

Pixel Counts

	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	47572	7465	3	0	3467942	3522982	3522982
Bare sand 2009	212612	94988	1592	757	61381	371330	371330
Beach dune herbland 2009	15525	97003	2714	242	5716	121200	121200
Marsh shrubland 2009	282	11490	23012	549	1	35334	35334
Water 2009	0	21	59	1378	0	1458	1458
Class Total	275991	210967	27380	2926	3535040	0	0
Class Changes	63379	113964	4368	1548	67098	0	0
Image Difference	95339	-89767	7954	-1468	-12058	0	0

Percentages

	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	17.237	3.538	0.011	0	98.102	100	100
Bare sand 2009	77.036	45.025	5.814	25.871	1.736	100	100
Beach dune herbland 2009	5.625	45.98	9.912	8.271	0.162	100	100
Marsh shrubland 2009	0.102	5.446	84.047	18.763	0	100	100
Water 2009	0	0.01	0.215	47.095	0	100	100
Class Total	100	100	100	100	100	0	0
Class Changes	22.964	54.02	15.953	52.905	1.898	0	0
Image Difference	34.544	-42.55	29.05	-50.171	-0.341	0	0

Area (Hectares)

	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	4.7572	0.7465	0.0003	0	346.7942	352.2982	352.2982
Bare sand 2009	21.2612	9.4988	0.1592	0.0757	6.1381	37.133	37.133
Beach dune herbland 2009	1.5525	9.7003	0.2714	0.0242	0.5716	12.12	12.12
Marsh shrubland 2009	0.0282	1.149	2.3012	0.0549	0.0001	3.5334	3.5334
Water 2009	0	0.0021	0.0059	0.1378	0	0.1458	0.1458
Class Total	27.5991	21.0967	2.738	0.2926	353.504	0	0
Class Changes	6.3379	11.3964	0.4368	0.1548	6.7098	0	0
Image Difference	9.5339	-8.9767	0.7954	-0.1468	-1.2058	0	0

Sand Island Change Detection 2009-2010

Pixel Counts

	Bare sand 2009	Beach dune herbland 2009	Marsh shrubland 2009	Water 2009	Unclassified	Row Total	Class Total
Unclassified	16284	1494	1	0	3349626	3367405	3367405
Bare sand 2010	307213	13603	100	0	171951	492867	492867
Beach dune herbland 2010	46839	97014	4729	250	1405	150237	150237
Marsh shrubland 2010	904	8622	30438	388	0	40352	40352
Water 2010	90	467	66	820	0	1443	1443
Class Total	371330	121200	35334	1458	3522982	0	0
Class Changes	64117	24186	4896	638	173356	0	0
Image Difference	121537	29037	5018	-15	-155577	0	0

Percentages

	Bare sand 2009	Beach dune herbland 2009	Marsh shrubland 2009	Water 2009	Unclassified	Row Total	Class Total
Unclassified	4.385	1.233	0.003	0	95.079	100	100
Bare sand 2010	82.733	11.224	0.283	0	4.881	100	100
Beach dune herbland 2010	12.614	80.045	13.384	17.147	0.04	100	100
Marsh shrubland 2010	0.243	7.114	86.144	26.612	0	100	100
Water 2010	0.024	0.385	0.187	56.241	0	100	100
Class Total	100	100	100	100	100	0	0
Class Changes	17.267	19.955	13.856	43.759	4.921	0	0
Image Difference	32.73	23.958	14.202	-1.029	-4.416	0	0

Area (Hectares)

	Bare sand 2009	Beach dune herbland 2009	Marsh shrubland 2009	Water 2009	Unclassified	Row Total	Class Total
Unclassified	1.6284	0.1494	0.0001	0	334.9626	336.7405	336.7405
Bare sand 2010	30.7213	1.3603	0.01	0	17.1951	49.2867	49.2867
Beach dune herbland 2010	4.6839	9.7014	0.4729	0.025	0.1405	15.0237	15.0237
Marsh shrubland 2010	0.0904	0.8622	3.0438	0.0388	0	4.0352	4.0352
Water 2010	0.009	0.0467	0.0066	0.082	0	0.1443	0.1443
Class Total	37.133	12.12	3.5334	0.1458	352.2982	0	0
Class Changes	6.4117	2.4186	0.4896	0.0638	17.3356	0	0
Image Difference	12.1537	2.9037	0.5018	-0.0015	-15.5577	0	0

Sand Island Change Detection 2010-2012

Pixel Counts

	Bare sand 2010	Beach dune herbland 2010	Marsh shrubland 2010	Water 2010	Unclassified	Row Total	Class Total
Unclassified	130139	831	0	0	3344488	3475458	3475458
Bare sand 2012	281086	27464	107	1	22820	331478	331478
Beach dune herbland 2012	60126	92196	6061	157	73	158613	158613
Marsh shrubland 2012	21516	29269	32384	408	24	83601	83601
Water 2012	0	477	1800	877	0	3154	3154
Class Total	492867	150237	40352	1443	3367405	0	0
Class Changes	211781	58041	7968	566	22917	0	0
Image Difference	-161389	8376	43249	1711	108053	0	0

Percentages

	Bare sand 2010	Beach dune herbland 2010	Marsh shrubland 2010	Water 2010	Unclassified	Row Total	Class Total
Unclassified	26.404	0.553	0	0	99.319	100	100
Bare sand 2012	57.031	18.28	0.265	0.069	0.678	100	100
Beach dune herbland 2012	12.199	61.367	15.02	10.88	0.002	100	100
Marsh shrubland 2012	4.365	19.482	80.254	28.274	0.001	100	100
Water 2012	0	0.317	4.461	60.776	0	100	100
Class Total	100	100	100	100	100	0	0
Class Changes	42.969	38.633	19.746	39.224	0.681	0	0
Image Difference	-32.745	5.575	107.179	118.572	3.209	0	0

Area (Hectares)

	Bare sand 2010	Beach dune herbland 2010	Marsh shrubland 2010	Water 2010	Unclassified	Row Total	Class Total
Unclassified	13.0139	0.0831	0	0	334.4488	347.5458	347.5458
Bare sand 2012	28.1086	2.7464	0.0107	0.0001	2.282	33.1478	33.1478
Beach dune herbland 2012	6.0126	9.2196	0.6061	0.0157	0.0073	15.8613	15.8613
Marsh shrubland 2012	2.1516	2.9269	3.2384	0.0408	0.0024	8.3601	8.3601
Water 2012	0	0.0477	0.18	0.0877	0	0.3154	0.3154
Class Total	49.2867	15.0237	4.0352	0.1443	336.7405	0	0
Class Changes	21.1781	5.8041	0.7968	0.0566	2.2917	0	0
Image Difference	-16.1389	0.8376	4.3249	0.1711	10.8053	0	0

Sand Island Change Detection 2007-2012

Pixel Counts

	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	63606	26699	468	24	3384661	3475458	3475458
Bare sand 2012	153262	51894	730	191	125401	331478	331478
Beach dune herbland 2012	41571	94075	4960	155	17852	158613	158613
Marsh shrubland 2012	17552	37172	20664	1087	7126	83601	83601
Water 2012	0	1127	558	1469	0	3154	3154
Class Total	275991	210967	27380	2926	3535040	0	0
Class Changes	122729	116892	6716	1457	150379	0	0
Image Difference	55487	-52354	56221	228	-59582	0	0

Percentages

	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	23.046	12.656	1.709	0.82	95.746	100	100
Bare sand 2012	55.532	24.598	2.666	6.528	3.547	100	100
Beach dune herbland 2012	15.062	44.592	18.115	5.297	0.505	100	100
Marsh shrubland 2012	6.36	17.62	75.471	37.15	0.202	100	100
Water 2012	0	0.534	2.038	50.205	0	100	100
Class Total	100	100	100	100	100	0	0
Class Changes	44.468	55.408	24.529	49.795	4.254	0	0
Image Difference	20.105	-24.816	205.336	7.792	-1.685	0	0

Area (Hectares)

	Bare sand 2007	Beach dune herbland 2007	Marsh shrubland 2007	Water 2007	Unclassified	Row Total	Class Total
Unclassified	6.3606	2.6699	0.0468	0.0024	338.4661	347.5458	347.5458
Bare sand 2012	15.3262	5.1894	0.073	0.0191	12.5401	33.1478	33.1478
Beach dune herbland 2012	4.1571	9.4075	0.496	0.0155	1.7852	15.8613	15.8613
Marsh shrubland 2012	1.7552	3.7172	2.0664	0.1087	0.7126	8.3601	8.3601
Water 2012	0	0.1127	0.0558	0.1469	0	0.3154	0.3154
Class Total	27.5991	21.0967	2.738	0.2926	353.504	0	0
Class Changes	12.2729	11.6892	0.6716	0.1457	15.0379	0	0
Image Difference	5.5487	-5.2354	5.6221	0.0228	-5.9582	0	0

APPENDIX E

EAST SHIP ISLAND QUALITATIVE DESCRIPTIONS OF CHANGES BETWEEN PHOTOGRAPHIC PAIRS FROM 2010-2012

East Ship Island Qualitative Descriptions

Photo pair number	Habitat Type	Pioneering on bare sand / algal flat	Vegetation cover	Dunes	Overwashing	Land loss / gain
1 North	Habitat type changed from algal flat to bare sand	Small patches of *Sesuvium sp.*dot the area and appear on higher elevations	New growth occurring in patches all around	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
1 East	Habitat type changed from algal flat to bare sand	Small patches of *Sesuvium sp.*dot the area and appear on higher elevations. Establishing *Uniola paniculata* in the background.	Vegetation cover in the background has increased	The building of one small dune in the background is noticeable	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
1 South	Habitat type changed from algal flat to bare sand	Small patches of *Sesuvium sp.* in the area.	vegetation cover has slightly increased in the background	The building of one small dune in the background is noticeable	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
1 West	Habitat type changed from algal flat to bare sand	Small patches of *Sesuvium sp.* in the area.	vegetation cover has moderately increased in the background	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
2 North	No change	Few patches of *Sesuvium sp.*	Slight increase in vegetation	Very slight dune building in the background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
2 East	No change	*Uniola paniculata* establishing in the background	Slight increase in vegetation	Slight dune building in the background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

2 South	No change	*Uniola paniculata* establishing in the background	Slight increase in vegetation	Slight dune building in the background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
2 West	No change	Small coverage of *Sesuvium sp.*	Slight increase in vegetation	No dunes present	No overwashing observed (cannot say)	Slight land gain noticeable
3 North	Habitat type changed from algal flat to bare sand	Emerging of *Uniola paniculata* and *Fimbristylis castanea* in background	Very slight increase in vegetation in background	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
3 East	Habitat type changed from algal flat to bare sand	Small patches of *Sesuvium sp.* in the area.	Moderate increase in vegetation in middle and background	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
3 South	Habitat type changed from algal flat to bare sand	*Uniola paniculata* establishing in the background	Slight increase in vegetation in the far background	Building of a small dune in the far background is noticeable	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
3 West	Habitat type changed from algal flat to bare sand	*Uniola paniculata* establishing in the background	Very slight increase in vegetation in background	No dunes present	No overwashing observed (cannot say)	Slight land gain noticeable
4 North	No change	*Fimbristylis castanea*, *Ipomoea imperati*, and *Panicum amarum* starting to colonize the area	Moderate increase in vegetation in middle and background	Some slight to moderate dune building in the middle and background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
4 East	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

4 South	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
4 West	No change	*Fimbristylis castanea*, *Ipomoea imperati*, and *Panicum amarum* starting to colonize the area	Moderate increase in vegetation in middle and background	Some slight to moderate dune building in the middle and background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 North	Habitat type changed from bare sand to beach dune herbland	*Fimbristylis castanea* colonizing the area	Moderate increase in vegetation in the fore, middle, and background	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 East	Habitat type changed from bare sand to beach dune herbland	*Fimbristylis castanea* colonizing the area	Major increase in vegetation in the fore, middle and background	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 South	Habitat type changed from bare sand to beach dune herbland	*Fimbristylis castanea* colonizing the area	Major increase in vegetation in the fore, middle and background	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 West	Habitat type changed from bare sand to beach dune herbland	*Fimbristylis castanea* colonizing the area	Major increase in vegetation in the fore, middle and background	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
6 North	No change	No new pioneering vegetation	Very slight increase in vegetation in background	Slight addition to the foredune in the background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
6 East	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	Extensive erosion of shoreline

6 South	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	Extensive erosion of shoreline
6 West	No change	No new pioneering vegetation	Very slight increase in vegetation in background	Slight addition to the foredune in the background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
7 North	No change	No new pioneering vegetation	Slight increase of *Ipomoea imperati* in the foreground	Slight addition to dunes in the foreground	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
7 East	No change	No new pioneering vegetation	Moderate increase in *Uniola paniculata* and *Ipomoea imperati* in the fore, middle and background. Addition also noticed in the coverage of *Panicum* amarum	Moderate building of dune in the middle ground	Slight evidence of overwashing	No land loss or gain noticed (cannot say)
7 South	No change	No new pioneering vegetation	Moderate increase in *Uniola paniculata* and *Ipomoea imperati*	Dunes appear stable in background	Slight evidence of overwashing in the foreground	No land loss or gain noticed (cannot say)
7 West	No change	No new pioneering vegetation	The loss of *Baccharis halimifolia* is noticeable in the background	Slight addition to all dunes in the area	Overwash scour channel appears to be wider	No land loss or gain noticed (cannot say)
8 North	Habitat type changed from marsh shrubland to beach dune herbland	No new pioneering vegetation	Loss of small *Baccharis halimifolia.* Increase in *Ipomoea imperati* and *Uniola paniculata*	The creation of a new dune is noticeable in fore and middle ground	Major overwashing occurred	No land loss or gain noticed (cannot say)

8 East	Habitat type changed from marsh shrubland to beach dune herbland	No new pioneering vegetation	Loss of small *Baccharis halimifolia.* Increase in *Ipomoea imperati* and *Uniola paniculata*	The creation of a new dune is noticeable in fore and middle ground	Major overwashing occurred	No land loss or gain noticed (cannot say)
8 South	Habitat type changed from marsh shrubland to beach dune herbland	No new pioneering vegetation	Major increase of *Uniola paniculata* especially in overwash channel	All dunes in the area have been reshape	Major overwashing occurred	No land loss or gain noticed (cannot say)
8 West	Habitat type changed from marsh shrubland to beach dune herbland	No new pioneering vegetation	Loss of all *Baccharis halimifolia* and most of the *Spartina patens.* Major increase in *Ipomoea imperati* and *Uniola paniculata*	All dunes in the area have been reshape	Major overwashing occurred	No land loss or gain noticed (cannot say)
9 North	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
9 East	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
9 South	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
9 West	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
10 North	No change	No new pioneering vegetation	*Baccharis halimifolia* has increased in density	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

10 East	No change	No new pioneering vegetation	New growth *Baccharis halimifolia* all around	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
10 South	No change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
10 West	No change	No new pioneering vegetation	New growth *Baccharis halimifolia* all around	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
11 North	No change	No new pioneering vegetation	New growth *Quercus geminata* in 2010 appears healthy and growth is apparent with increased coverage	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
11 East	No change	No new pioneering vegetation	New growth *Quercus geminata* in 2010 appears healthy and growth is apparent with increased coverage	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
11 South	No change	No new pioneering vegetation	New growth *Quercus geminata* in 2010 appears healthy and growth is apparent with increased coverage	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
11 West	No change	No new pioneering vegetation	New growth *Quercus geminata* in 2010 appears healthy and growth is apparent with increased coverage	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

APPENDIX F

EAST SHIP ISLAND QUANTITATIVE TABULATION OF CHANGES BETWEEN PHOTOGRAPHIC PAIRS FROM 2010-2012

East Ship Island Change Types

Photo pair number	Change did occur	Habitat type	Pioneering species on bare sand / algal flat	Vegetation cover Increase	Vegetation cover decrease	Vegetation cover no change	Dune building	Dune erosion	Overwash	Land loss	Land gain
1 North	1	1	1	1							
1 East	1	1	1	1			1				
1 South	1	1	1	1			1				
1 West	1	1	1	1							
2 North	1		1	1			1				
2 East	1		1	1			1				
2 South	1		1	1			1				
2 West	1		1	1							1
3 North	1	1	1	1							
3 East	1	1	1	1							
3 South	1	1	1	1			1				
3 West	1	1	1	1							1
4 North	1		1	1			1				
4 East						1					
4 South						1					
4 West	1		1	1			1				
5 North	1	1	1	1							
5 East	1	1	1	1							
5 South	1	1	1	1							
5 West	1	1	1	1							
6 North	1			1			1				
6 East	1					1				1	
6 South	1					1				1	
6 West	1			1							
7 North	1			1			1				
7 East	1			1			1		1		
7 South	1			1					1		
7 West	1			1							
8 North	1	1			1		1		1		
8 East	1	1			1		1		1		
8 South	1	1		1	1		1		1		
8 West		1			1		1		1		
9 North						1					
9 East						1					
9 South						1					
9 West						1					
10 North	1			1							
10 East	1			1							
10 South	1					1					
10 West	1			1							

11 North	1			1							
11 East	1			1							
11 South	1			1							
11 West	1			1							
Total	37	16	18	32	4	9	15	0	6	2	2
percentage of total	84	36	41	73	9	20	34	0	14	5	5

APPENDIX G

EAST SHIP ISLAND RTK ELEVATION SURVEY RESULTS

East Ship Island RTK Survey

Sample point	Latitude	Longitude	Elevation (ft)	Elevation (m)	Hz Prec (ft)	Vt Prec (ft)	PDOP	Sats
1	271512.998	970825.549	1.314	0.401	0.172	0.261	1.9	8
2	271149.589	970707.992	1.020	0.311	0.081	0.122	1.9	8
3	270941.085	969777.146	1.007	0.307	0.112	0.201	2.5	7
4	269923.085	969710.716	2.242	0.683	0.026	0.052	1.5	15
5	269905.484	968882.172	1.348	0.411	0.028	0.056	1.5	15
6	267823.655	967267.759	2.132	0.650	0.030	0.056	1.4	15
7	267763.441	966580.752	9.042	2.756	0.028	0.052	1.4	15
8	267643.594	966272.054	6.219	1.896	0.025	0.042	1.2	17
9	268573.71	966831.034	1.067	0.325	0.029	0.055	1.4	17
10	268348.205	967135.459	1.194	0.364	0.028	0.058	1.5	15
11	268292.873	967077.399	6.225	1.897	0.046	0.085	1.5	16

Minimum (m)	0.307
Maximum (m)	2.756
Mean (m)	0.909
Standard Deviation	0.857

APPENDIX H

SAND ISLAND QUALITATIVE DESCRIPTIONS OF CHANGES BETWEEN PHOTOGRAPHIC PAIRS FROM 2010-2012

Sand Island Qualitative Descriptions

Photo pair number	Habitat Type	Pioneering on bare sand / algal flat	Vegetation cover	Dunes	Overwashing	Land loss / gain
1 North	No Change	No new pioneering vegetation	Slight increase in vegetation in the background appears to be *Uniola paniculata*	Growth in elevation to the dune in background is apparent	No overwashing observed (cannot say)	Slight land loss due to erosion of shoreline
1 East	No Change	No new pioneering vegetation	Vegetation in the background appears to be more dense	Dunes are appear stable	No overwashing observed (cannot say)	Moderate land loss due to erosion of shoreline
1 South	No Change	No new pioneering vegetation	Species pioneering in 2010 are now gone	No dunes present	No overwashing observed (cannot say)	Moderate land loss due to erosion of shoreline
1 West	No Change	No new pioneering vegetation	Species pioneering in 2010 are now gone	No dunes present	No overwashing observed (cannot say)	Major land loss due to erosion of shoreline
2 North	Habitat changed from bare sand to beach dune herbland	New patches of *Fimbristylis castanea* and *Panicum amarum* scattered around in the fore and middle ground	Slight increase of vegetation in the fore, middle, and background	Dunes in the background appear to have eroded and possibly truncated	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
2 East	Habitat changed from bare sand to beach dune herbland	New patches of *Fimbristylis castanea* and *Panicum amarum* scattered around in the fore and middle ground	Moderate increase of vegetation in the fore, middle, and background	Dunes in the background appear to have eroded and possibly truncated	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

2 South	Habitat changed from bare sand to beach dune herbland	New patches of *Fimbristylis castanea* and *Panicum amarum* scattered around in the fore and middle ground. New growth *Spartina alterniflora* on shoreline	Moderate increase of vegetation in the fore, middle, and background	No dunes present	No overwashing observed (cannot say)	Significant land loss but appears to be stabilizing with vegetation
2 West	Habitat changed from bare sand to beach dune herbland	New patches of *Fimbristylis castanea, Uniola paniculata*, and *Panicum amarum* scattered around in the fore and middle ground	Moderate increase of vegetation in the fore, middle, and background	No dunes present	No overwashing observed (cannot say)	Slight land loss can be seen in far background
3 North	Habitat changed from bare sand to beach dune herbland	New patches of *Heterotheca subaxillaris* starting to colonize in the foreground	Moderate increase of vegetation in the fore, middle, and background	Slight increase in dune elevation noticeable	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
3 East	Habitat changed from bare sand to beach dune herbland	No new pioneering vegetation	Moderate increase of vegetation in the fore, middle, and background	Slight increase in dune elevation noticeable	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
3 South	Habitat changed from bare sand to beach dune herbland	No new pioneering vegetation	Major increase of vegetation in the fore, middle, and background	No dunes present	No overwashing observed (cannot say)	Some land gain apparent in the background
3 West	Habitat type changed from bare sand to beach dune herbland	No new pioneering vegetation	Major increase of vegetation in the fore, middle, and background	No dunes present	No overwashing observed (cannot say)	Some land gain apparent in the background
4 North	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

4 East	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
4 South	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
4 West	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 North	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 East	No Change	No new pioneering vegetation	Vegetation cover increase density	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 South	No Change	No new pioneering vegetation	Vegetation cover increase density	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
5 West	No Change	No new pioneering vegetation	Vegetation cover increase density	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
6 North	No Change	No new pioneering vegetation	Increase in *Morella cerifera* densities and coverage	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

6 East	No Change	No new pioneering vegetation	Vegetation cover increase density	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
6 South	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
6 West	No Change	No new pioneering vegetation	Increase in *Morella cerifera* densities and coverage	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
7 North	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
7 East	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
7 South	No Change	No new pioneering vegetation	Moderate increase of vegetation in the fore, middle, and background	Slight increase in dune elevation noticeable	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
7 West	No Change	No new pioneering vegetation	Moderate increase of vegetation in the fore, middle, and background	Moderate erosion of dunes in background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
8 North	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

8 East	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
8 South	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
8 West	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
9 North	No Change	No new pioneering vegetation	Large dense patches of *Lythrum lineare* previously undocumented on MS-AL barrier island chain are notable	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
9 East	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
9 South	No Change	No new pioneering vegetation	Large dense patches of *Lythrum lineare* previously undocumented on MS-AL barrier island chain are notable	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
9 West	No Change	No new pioneering vegetation	Large dense patches of *Lythrum lineare* previously undocumented on MS-AL barrier island chain are notable	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
10 North	No Change	No new pioneering vegetation	Moderate increase of vegetation in the fore, middle, and background. Increase in *Paspulum sp.*	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

10 East	No Change	No new pioneering vegetation	Moderate increase of vegetation in the fore, middle, and background. Increase in *Paspalum sp.*	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
10 South	No Change	No new pioneering vegetation	No change in vegetation observed	No dunes present	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)
10 West	No Change	No new pioneering vegetation	Moderate increase of vegetation in the fore, middle, and background. Increase in *Paspulum sp.*	Slight erosion of dune in the background	No overwashing observed (cannot say)	No land loss or gain noticed (cannot say)

APPENDIX I

SAND ISLAND QUANTITATIVE TABULATION OF CHANGES BETWEEN PHOTOGRAPHIC PAIRS FROM 2010-2012

Sand Island Change Types

Photo pair number	Change did occur	Habitat type	Pioneering species on bare sand / algal flat	Vegetation cover Increase	Vegetation cover decrease	Vegetation cover no change	Dune building	Dune erosion	Overwash	Land loss	Land gain
1 North	1			1			1			1	
1 East	1			1						1	
1 South	1				1					1	
1 West	1				1					1	
2 North	1	1	1	1			1				
2 East	1	1	1	1			1				
2 South	1	1	1	1						1	
2 West	1	1	1	1						1	
3 North	1	1	1	1			1				
3 East	1	1		1			1				
3 South	1	1		1							1
3 West	1	1		1			1				1
4 North						1					
4 East						1					
4 South						1					
4 West						1					
5 North						1					
5 East	1			1							
5 South	1			1							
5 West	1			1							
6 North	1			1							
6 East	1			1							
6 South						1					
6 West	1			1							
7 North						1					
7 East						1					
7 South	1			1			1				
7 West	1			1				1			
8 North						1					
8 East						1					
8 South						1					
8 West						1					
9 North	1			1							
9 East						1					
9 South	1			1							
9 West	1			1							
10 North	1			1							
10 East	1			1							
10 South						1					
10 West	1			1				1			
Total	26	8	5	24	2	14	7	2	0	6	2
percentage of total	65	20	13	60	5	35	18	5	0	15	5

APPENDIX J

SAND ISLAND RTK ELEVATION SURVEY RESULTS

Sand Island RTK Survey

Sample point	Latitude	Longitude	Elevation (ft)	Elevation (m)	Hz Prec (ft)	Vt Prec (ft)	PDOP	Sats
1	262769.344	1081765.849	1.815	0.553	0.039	0.067	1.6	15
2	262313.879	1082625.302	2.260	0.689	0.038	0.064	1.6	15
3	262669.333	1082918.731	4.725	1.440	0.032	0.052	1.5	15
4	262949.71	1084324.564	12.507	3.812	0.036	0.051	1.3	16
5	263288.623	1084544.955	4.613	1.406	0.033	0.050	1.3	16
6	263233.542	1083002.021	5.376	1.639	0.032	0.050	1.4	17
7	264034.903	1082820.892	2.920	0.890	0.031	0.049	1.3	17
8	263701.378	1082570.162	1.489	0.454	0.033	0.051	1.3	17
9	263851.181	1081993.021	1.634	0.498	0.037	0.056	1.3	16
10	263630.52	1081973.533	1.017	0.310	0.032	0.048	1.4	15

Minimum (m)	0.310
Maximum (m)	3.812
Mean (m)	1.169
Standard Deviation	1.039

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